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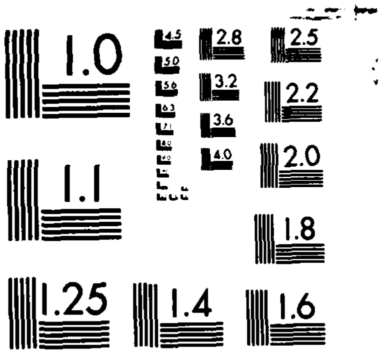

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Technical Report HL-82-7

DREDGING: AN ANNOTATED BIBLIOGRAPHY ON
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Installment 3

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PREFACE

This bibliography was begun under the Improvement of Operations and Maintenance Techniques (IOMT) research program, sponsored by the Office, Chief of Engineers (OCE). It is being continued, using funds provided by the Water Resources Support Center Dredging Division and the Operations Division, Civil Works Office.

Installment 3 of this bibliography was published by the Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station (WES) under the general supervision of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; W. H. McAnally, Acting Chief of the Estuaries Division; and G. M. Fisackerly, Acting Chief of the Sedimentation Branch. Mr. T. W. Richardson was the project engineer, and Mr. E. W. Flowers supervised the acquisition and compilation of bibliographic material. Dr. A. R. Faust of Carrollton, Texas, provided abstracting services under contract to WES. Recognition is made of the following persons who worked on the bibliography: Ms. P. C. Habeeb, Mr. G. R. Clark, and Mr. M. P. Alexander.

Commander and Director of WES during the publication of this bibliography was COL Robert C. Lee, CE. Technical Director was Mr. F. R. Brown.

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INSTALLMENT 3

Reference Numbers 0877 - 1249

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A

0877 ABRAHAM, J. L. 1968. "Under Water Drilling and Blasting," Proceedings, World Dredging Conference, WODCON II, pp 373-398.

A history of "breaking up rock underwater" is given from the time of the Phoenicians (2,000 years ago) to modern time drilling and blasting using sophisticated techniques. Demands for underwater rock removal have come about primarily because of the need for deeper harbors for bulk carriers, but submarine mining also is a realistic use. Submarine drills and blasting were used as early as 1888 in the Panama Canal construction. Until the early 1950's, drilling and blasting was carried out by stationary drill barges, divers using compressed-air rock drills, and by a chisel-point rock breaker that weighed 5 to 30 tons. The Lindo Rig came into widespread use after the early 1950's. It drills holes, places casing, and allows many charges to be set off on a later date using detonator cord. Floating and quickly maneuverable drilling barges were the next advance, allowing blasting of up to 8,000 cubic yards of rock per week. Development of a catamaran-type of drill barge (102 feet long with a 57-foot beam) permits drilling in rougher waters and extremely high winds. A variety of charging patterns for rocks are discussed, along with the necessity to drill and charge considerably deeper than needed to avoid leaving unwanted rock ridges. Finally, the development of new types of gelatin explosives are discussed and several examples are given in which highly controlled explosive work is required.

0878 ACKERMAN, N. L. and NIYOMTHAI, C. 1964 (Mar). "Development of a Solid-Liquid Flow Meter," Journal, Hydraulics Division, ASCE, Vol 90, No. HY2, pp 121-139.

A theoretical explanation is given and an experimental meter is tested for measuring individual flow rates of the solid and liquid phases of sand-water mixtures in pipes of various sizes. Equations considering the continuity, momentum, and energy relationships for flow in the meter allowed theoretical determination of discharges. The range of application was intended to cover conditions from the case of flow of a homogeneous fluid to the two-phase case where the solids phase component settling velocity is large compared to the fluid velocity. For certain cases, a trial and error procedure was used to successively approximate and improve estimates of friction loss, which in turn allowed more nearly correct flow rate estimates. Laboratory tests on the experimental meter showed that the total discharge and volumetric concentration of solids in a slurry can be accurately predicted. Total discharge can be predicted within 2 percent for most flow conditions, while solid content can be predicted within 0.5 percent for almost all flow conditions investigated.

0879 ACOSTA, A. J. 1954 (Jul). "An Experimental and Theoretical Investigation of Two-Dimensional Centrifugal-Pump Impellers," Transactions, American Society of Mechanical Engineers, Vol 76, No. 5, pp 749-763.

A theoretical mathematical treatment is presented for a hydraulic machine (consisting of an inlet or guide, a rotating impeller, and stationary diffusing and collecting device). The impeller is responsible for energy flow and is the first item of interest. Attention is given to the radial flow or "centrifugal" impeller, in which the main feature is the great change of radius from impeller inlet to exit. The theoretical treatment considers: the mapping function, the displacement flow, the through flow, the developed head, the condition of shockless entry, and pressure and velocity distribution. Computed values of flow description were compared to actual values of the developed head and pressure distribution on vane surfaces of two, four, and six-vaned logarithmic spiral impellers. The blade shape of a logarithmic spiral was selected for study because the vane has a constant angle, which is mathematically convenient, but also because most blade designs in actual practice closely resemble such spirals. For analysis, flow is assumed to be inviscid, incompressible, and irrotational to apply methods of theory. Agreement between predictions and observations are reasonably good for points where influence of the inlet turn on internal flow is least; discrepancies at other flow rates are attributed to real fluid effects observed in the impeller passages. It was suggested that phenomena not connected with the vanes alone are important in changing flow rates.

0880 ADAMS, D. B. 1970. "Insurance for the Dredging Industry; A Review and Analysis," Proceedings, World Dredging Conference, WODCON III, pp 461-468.

Insurance is a business cost to dredging, equally as important as wages or taxes. Dredging insurance, like dredging itself, has become more of an international business. Insurance is important in dredging because it first is a requirement before doing business, and secondly, because it puts operations on an economically sound basis. Through insurance, big or small losses can be put on a more or less "fixed-cost basis" for efficient operation. Insurance to dredging firms is based primarily on five areas of "exposure." The first of these is liability, which includes liability for bodily injury, pollution damage, and many other aspects. The second is physical loss or damage to company assets--its dredges. The third area is consequential loss, that resulting from sales or income slumps after physical loss. A fourth area is "performance," the remedy of which is bonding to assure company and employee performance. A final area is general security of employees, including mostly what are termed "company benefits." Several things which must be considered for primary underwriting of marine insurance include management (who runs the company and how); the firm's past insurance experiences; the types, locations, and conditions of work done by the company and, of utmost importance, the fleet itself--ages, types, values, and conditions of the vessels. Underwriters are favorably inclined to companies with continuous preventive maintenance programs.

0881 ADDIE, R. R. 1980 (Jul). "Slurry Pump and Pipeline Performance Testing," World Dredging and Marine Construction, Vol 16, No. 7, pp 11-12.

The Georgia Iron Works Laboratory was established in 1976 to test performance of its own line of centrifugal slurry pumps. Customer demand caused expansion to contract work for other firms. The company also carries out research and development on pumps. The testing equipment includes five test loops. They consist of 3-inch, 4-inch, 6-inch, 8-inch, and 18-inch-diameter pipelines, each with its own pump and electric motor drive. The 18-inch line has its own 2,000-horsepower, 4,160-volt motor, and can handle flows up to 30,000 gallons per minute. Another test loop is a special 80-foot-high, 8-inch-diameter vertical pipe column for vertical slurry transport testing. Extensive monitoring equipment includes several types of flowmeters, bend meters, orifice plates, watt meters and temperature transducers. Every important reading is duplicated or has at least one backup system. Glass sections are provided in special variable incline pipeline sections for visual observations. A mini-computer is used for monitoring, calculation, and storage of up to 32 channels of data at 4,400 readings per second. Since the laboratory's inception, 600 pump tests have been made; 100 of those were slurry tests. On pump research, work has centered on improved efficiency and suction performance.

0882 ALVES, G. E., BOUCHER, D. F., and PIGFORD, R. L. 1952 (Aug). "Pipeline Design for Non-Newtonian Solutions and Suspensions," Chemical Engineering Progress, Vol 48, No. 8, pp 385-393.

Transport of solid-in-liquid suspensions and solutions in pipelines is discussed. A large proportion of such materials are non-Newtonian in character; that is, they do not have a constant viscosity at a given temperature and concentration. The flow properties of non-Newtonian suspensions and solutions are evaluated with respect to pipeline-type viscometers and rotational-type viscometers, and a method is shown for scale-up to design of production plant pipelines. Most solutions and suspensions are Newtonian at low-concentrations, changing to non-Newtonian when a certain critical concentration is reached. In the case of suspensions, this critical concentration depends on particle size and shape and upon degree of dispersion, as well as on concentration. Experimental data are given from tests on four representative materials using the different viscometers, and a comparison of the two viscometers' performance is made. The article concludes by discussing the applicability of using different types of pumps for different suspensions: centrifugal pumps, diaphragm pumps, and other types. Open impellers were recommended where particle size is large or where particles would tend to clog small passages in a closed impeller.

0883 AMBROSE, H. H. 1952 (Jun). "The Transportation of Sand in Pipes; Part II, Free-Surface Flow," Proceedings, Fifth Hydraulics Conference, pp 77-78.

Theoretical derivations and experimental data are discussed relevant to transport of sand-fluid mixtures in pipes. The discussion is limited to free-surface flow, and full-pipe flow is treated only as a limited condition. Emphasis is placed on geometry rather than on sediment concentration. Variables pertinent to describing the flow change with time and distance; hence, dealing with variable averages becomes necessary. Twelve variables are used in derivations with respect to the fluid, the sediment, the pipe, and general physical constants. The author acknowledges that because of the many variables and extreme complexity of transport mechanics, a rigorous derivation of the transport function has not been possible. As a minimum, two relationships are required to define the phenomenon: a transport function (relating transport to the geometry and other characteristics of flow, channel, and sediment), and a discharge function (relating discharge to resistance to flow from sandbed or pipe wall). The derivations center on the mean flow velocity and geometry. The limiting condition of primary interest for maintenance of sediment-free pipes is described as the "slope of impending deposition." Several experimental cases are discussed. For all three cases, the transport function was solely dependent upon mean geometry. Once sediment has deposited in a pipe, it was shown that an increase in transportability is required to carry away the deposit over that which was required to maintain the same sediment in continuous motion before deposit.

0884 ANDREAE, J. F. R. 1970. "The Aspects of Offshore Landreclamation: Yesterday, Today and Tomorrow," Proceedings, World Dredging Conference, WODCON III, pp 469-494.

After presenting a brief history of sand dredging by man, animals, and steam-powered machines, this article is devoted to discussing a variety of aspects of dredging within the recent two decades: why it is done, what are the consequences, some new concepts, the dredger, and economical aspects. One important reason for going into the sea is development of harbors along rivers or coasts. The sand balance is discussed in detail; that is, adapting quantities of sand to be dredged with quantity needed for reclamation so as to make execution of large projects economical and not end up with a shortfall or oversupply of dredged material. The advent of supertankers and ports or airports near large coastal cities, that are limited with respect to inland development, are cited as large projects needing proper planning. On a shallow coast, a combined harbor/airport development is recommended to utilize dredged material. Several types of studies that are carried out for large reclamation projects are listed and described. These include studies of hydraulic regime, harbor entrance design, changing flow patterns, and storm level protection. Hypothetical schemes are given for dealing with littoral drift, and a new concept of an all-sand breakwater is described. The author notes that dredgers in recent years have increased worldwide both in size and number to accommodate the increasing needs for large projects.

0885 ARMSTRONG, R. H. 1949. "Pressure Loss in Piping Systems; A Comparison of Conventional Factors for Fluid Friction in Piping Components," Report AECU-454, U. S. Atomic Energy Commission, Argonne National Laboratory.

Head loss coefficients are compared for three situations: sudden pipe contraction, sudden pipe enlargement, and for 90-degree bends. The values of the fraction of velocity head loss reported by 13 different authors or engineering research groups are compared, and curves are constructed to show how each researcher varied for each of the three situations. All authorities were in agreement for the sudden enlargement case. Considerable variation existed among each set of curves for the other two situations. It was noted that there was a lack of accurate data for the sudden contraction case for pipes larger than a 10-inch diameter. Fractional loss of velocity head is discussed for vaned elbows in 90-degree bends. Values reported range from 0.136 to 0.25; however, the author believes loss could be reduced to 0.12 through careful design. The major conclusion is that loss coefficients in common use have been satisfactory for the average system, but in a highly critical system it is necessary to evaluate the coefficients more accurately through a comprehensive testing program.

B

0886 BAARS, C. 1971 (Jun). "Bucket Wheel Design for Offshore Tin Dredging," Hydrospace, Vol 14, No. 3, pp 25-27.

Bucket-type dredgers for recovery of ore in alluvial deposits have been in use since before 1900. In 1908, two tin dredgers in Thailand could dig to 45 feet with 7-cubic-foot buckets. Dredging depth gradually increased to over 100 feet, but the ladder tackle became overly wieldy with the enormous weight of the bucket chain, long ladder, and great number of turning points and movable parts. A new system is described for deep ore recovery. The principles of using a revolutionary bucket wheel design (not requiring a bucket chain), power supplied to motors in the cutting wheel, and a number of other innovations make the new dredger effective. Inside the rotating body of the cutting wheel, a suction mouth is arranged in such a way that water is only sucked through cutting edges when they arrive in the cutting position. Material is cut loose, suspended, and even further dispersed higher up the suction tube so that ore delivered to the screen is much better disintegrated than if it came compacted from buckets. A complete description of bucket wheel operation and parts is given along with nine advantages of this type of cutting wheel and associated equipment. Because of reduced weight and fewer rotating and wearing parts, power consumption is much lower than on earlier conventional bucket dredgers.

0887 BAGNOLD, R. A. 1963. "Mechanics of Marine Sedimentation," The Sea: Ideas and Observations, Vol 3, pp 507-528.

After defining marine sediment and classifying grains according to origin, several theoretical and mathematical derivations are presented related to beach and nearshore sediment transport. Among transport phenomena dealt with are fall through the sea, transport over the sea bed, transport rate and fluid "power," auto-suspension of sediment, wave drift, and migration of sand by wave action. It is noted that, while bedded sands (nearshore) are relatively impermeable and have small pores among them, pebbles and larger materials are very permeable and permit considerable energy losses. This probably explains why the same wave attack displaces much more large-grained material than small-grained particles. Measurements and prediction of shoreward and longshore sediment movement are given. Longshore transport of sand is estimated from observed rates of erosion or accretion, and no satisfactory relationship has been developed between the rate of littoral transport and the waves and currents that cause it. This problem is discussed and a model for longshore sand transport is presented. The conclusion emphasizes that a sound understanding of natural littoral processes awaits further experimentation, especially in the areas of mechanics of wave motion in and near the surf zone, the budget of water flowing in nearshore circulation systems, and the modes and mechanics of sand transport along the beach. Wave energy transforms and dissipation required more study.

0888 BAGNOLD, R. A. 1966. "An Approach to the Sediment Transport Problem from General Physics," Geological Survey Professional Paper 422-I, U. S. Government Printing Office, Washington, D. C.

A new theory, backed by a number of corollary ideas, is proposed regarding sediment transport in open channels (streams and rivers, primarily). Reasoning is taken from a number of general physical principles and from in-depth studies of data and theories from various authors. So many theories abound (and they have no indisputable quantitative basis) that no commonly acceptable opinion and equation for such two-phased (liquid-solid) flow has been established. Reasons for this are explained. The object of the entire study is to predict transport of solids (primarily bedload) by rivers. For simplicity, conditions are restricted to these: (1) a steady, open-channel flow by gravity is involved; (2) there is unlimited availability of transportable solids; (3) concentration of transported solids is low enough that the tangential gravity pull in comparison to tractive stress can be neglected; and (4) it is a statistically steady system, representative of conditions along a channel, not just at a cross section. These conditions eliminate many types of flows except in natural rivers and laboratory flumes. After detailed analyses of factors affecting transport and comparisons of 146 actual measurements with predicted values, one of the key findings is that factual inadequacy on sediment transport exists because no data exist purely on unsuspended transport (particles in saltation). This, of course, results from the inability to separate, experimentally, bedload transport from turbulent suspension transport. This theory accounts for saltation even in laminar flow with the absence of turbulence.

0889 BAIN, A. G. and BONNINGTON, S. T. 1970. "The Hydraulic Transport of Solids by Pipeline," Pergamon Press, Oxford.

Hydraulic transport of solids has long been recognized as a convenient means of conveying, but it is only comparatively recent that this method has been considered as an alternative to traditional forms of dry transport for bulk handling over long distances. In order to decide if hydraulic transport will be a practical and economical alternative, operating, pumping and pipeline, and drying plant costs must be known. This book emphasizes interactions of a number of facets of a hydraulic transport project, and provides background information for calculation of flow variables and understanding of their significance. Flow properties are shown to be closely related to size distribution. Data and illustrations come primarily from the British Hydro-mechanics Research Association and the Central Electricity Generating Board. After giving an introduction to solids transport, settling and non-settling slurries are considered. Other chapters are dovoted to pumps, solids feeding systems, pipes and pipelines, and the recovery of solid material after transport. Two concluding sections cover installation, design, and operation; and system design and economics, respectively. Theory is dealt with in adequate detail to enhance understanding the principles put forth. The text is profusely illustrated.

0890 BAIN, A. G. and ELLIOTT, D. E. 1964 (Oct). "Coal Pipelines," International Pipes and Pipelines, Vol 9, No. 10, pp 45-52.

An array of uses, problems, and economic strategies concerning coal slurry pipelines is presented, along with recent investigations worldwide for improving efficiency and economy. A brief history of coal pipelines is given, comparing a 1913 model (660 yards long) with more modern pipelines. Short distance pumping is pointed out as using the coal in an "an received" (1/2 inch to 0) state with no further grinding nor thermal dewatering required. This coal must be pumped at relatively high velocity, causing greater power costs, pipe abrasion, and degradation of the coal fragments. A distance limit using this approach seems to be about 30 miles. Long distance pumping achieves lower costs per ton mile by reducing coal size and thereby minimizing pipeline and pumping costs at the expense of higher costs of coal preparation and drying. A much lower pressure drop occurs in larger lines (10-inch) at any pumped slurry velocity than for smaller lines (4-inch). The author introduces methods of using waste steam for more efficient thermal drying. Coal preparation (sizing), and the possibilities of developing pneumatic transport of coal or coal/oil slurries and coal/natural gas mixtures are discussed. Pipeline transport in general is summarized as being less aesthetically offensive, using less operating power, and requiring fewer personnel for operation and maintenance.

0891 BAKER, R. 1978 (Sep). "Submerged Pipeline Solves Disposal Problem," World Dredging and Marine Construction, Vol 14, No. 9, pp 20-26.

An innovative means is described for dredging of the small boat harbor at Muscatine, Iowa, on the Upper Mississippi River. In order to protect extensive nearby freshwater mussel beds on the river bed, normal river channel disposal of dredged material was ruled out by a group of State and Federal agencies. The dredging contractor eventually was required to pump the material about 5,000 feet to a borrow pit inside a protective levee on the opposite shore (in Illinois). Using two dredges, one as a dredger and one as a booster pump, the job was completed with no impairment to river navigation. This was done by using a plastic pipeline, submerging the portion across the river (1,800 feet) by using railroad track weights, completing the dredging, and then refloating the line and quickly uncoupling it. Few problems were encountered except that river work was extremely cumbersome and took every craft available to position the pipe ends and make the connections in strong midriver currents. Channel depth at low water in this area is 20 feet. Because the river gets turbid naturally, before another maintenance dredging, a study will be made to prove or disprove that damage would be incurred by the clam beds from silt disposal in the open river.

0892 BARDILL, J. D., CORSON, D. R., and WYMENT, W. R. 1962. "Factors Influencing the Design of Hydraulic Backfill Systems; Part Two, Friction-head Losses of Barite and Limestone Slurries During Pipeline Transport," Report of Investigations No. 6066, Department of Interior, Bureau of Mines.

most economical velocity will be the maximum obtainable with the equipment (this idea is later refuted); and (7) for many materials, there is a narrow range of velocities in which maximum output can be obtained.

0922 BRUUN, P. 1974 (Jul). "Bypassing Sediment--Plants and Arrangements," Dock and Harbour Authority, Vol 55, No. 645, pp 91-94.

A total of 34 "sand bypassing plants or arrangements" at harbors or tidal entrances throughout the world are summarily tabulated and discussed. The difference between the harbors and tidal entrances lies in the action of tidal currents. In the case of harbors, sediment bypassing may be designed solely on wave mechanics principles; at tidal inlets, current mechanics principles also may be applied. In either case, the finer the material, and the rougher the sea, the larger is that part of the sediment which bypasses on its "own power." Bypassing serves two purposes: (1) protection of navigation channels against deposits by longshore littoral drift, and (2) protection of downdrift-side beaches against starvation caused by the littoral drift barrier. Of the many types of trap arrangements, the most reliable and effective (but also most costly) is a detached breakwater built offshore on the updrift side. Most developments, however, involve a flexible arrangement of traps allowing dredging by floating equipment to easily bypass the material across the littoral drift barrier. Brief discussions are presented on new techniques such as submersible dredges, jet pumps for local agitation of sediments, and deep-water techniques.

0923 BUCK, G. F. 1980 (Oct). "A Dredged Fill for Coastal Logging," Proceedings, World Dredging Conference, WODCON IX, pp 889-898.

A unique fill island (8.1 hectares) was constructed with a 26-inch cutter head dredge in 15 days; about 402,000 cubic meters of silty sand was obtained to deepen one area and produce an artificial log sorting yard and an access causeway for a commercial operation. The filling operation was in an estuarine area near Vancouver Island, British Columbia. Height of the fill was 1.5 m above high tide. Because the area is sensitive ecologically and a valuable fishery and fish nursery area, the project area was dyked off first. The fill area contained a weir outlet, and water samples were taken to monitor possible adverse conditions of turbidity, dissolved oxygen concentration, and release of hydrogen sulfide. All parameters remained within limits for approval by fisheries experts for project completion. After filling, the dyked area contained 20 cm of newly deposited fine sediment. As the containment area was filled, an outer protective layer of gravel was added to the site to prevent erosion. The company using the area has had excellent performance on the fill for over 2 years. Construction cost was $731,000 Canadian.

0924 BUNCE, E. B. 1965 (Mar). "Two-Stage Dredging Method Allows Continuous Operation," Construction Methods and Equipment, Vol 47, No. 3, pp 84-89.

business, and diesel engines came into widespread use. During the more recent decade, further industrial developments have taken place and the need for port and channel facilities for the large, deep-draft supertankers has arisen. Among the industrial users of the new and larger ports are the oil developers/shippers. This forecast is based on early 1970's oil reserve patterns compared to worldwide oil consumption patterns. Another increasing seaborne trade is iron ore, but its increase is only about one-fourth that of petroleum. Mr. Brouwer points out that dredging people need to follow the lead of other industries in cooperating, and to quit maintaining a "low profile." He also notes that the industry is "well able to cope with whatever rational or irrational environmental arguments are raised against its operations."

0920 BROWN, C. 1969 (Oct). "Quick Ditch Method Blasts Pipeline Trenches," World Dredging and Marine Construction, Vol 5, No. 9, p 28.

An underwater method of blasting using special shaped charges has been developed by Jet Research Center, Inc., to eliminate the need for initial boring through coral or rock to place conventional charges. This method not only allows work on laying pipelines or deepening harbors to proceed more quickly, but it also reduces problems encountered in very shallow water by deep-draft floating platforms used conventionally to dig trenches. The method also is applicable in locations where rock formations are too hard to be broken up or removed economically by standard ditching or dredging equipment. The system, which is entirely portable by airplane, uses shaped charges in a certain pattern to crush rock formations as deep as 10 to 12 feet, if necessary. The article concludes with four examples of using the "Quick Ditch" system in Egypt, Alaska, Mexico, and the Iran-Persian Gulf. The operations require a minimum of personnel. With proper application, the system produces crushed rock of a size suitable for dredging.

0921 BROWN, F. R. ET AL. 1938 (Dec). "Transportation of Sand and Gravel in a Four-Inch Pipe; Discussion," Proceedings, ASCE, Vol 64, No. 10, pp 2081-2090.

This article presents written responses by four individuals to articles presented by other researchers in the field of mixed flow (solid-liquid phases) in a pipeline. It is evident that all four respondents see the need for much more testing and refinement of formulas from experimental data. Among the many key points made are that: (1) the friction factor in pipes transporting material increases with the percentage of material and decreases with velocity; (2) friction factor curves for sand approach those for clear water, and the two curves coincide at higher velocities; (3) the data discussed may not be completely applicable to full-sized dredge pipes (12 to 30 inches in diameter); (4) the effects of the particle sizes of handled materials should be more closely investigated; (5) for each variety and percentage of sand there is a pipe-blocking velocity below which complete shutoff occurs; (6) as long as a dredge can pick up a full load for its pipeline, the

fluidized solids. The technique is compared to theories and data of several authors, including Einstein's formula for the apparent viscosity of a dilute suspension of spherical particles.

0917 BREUSERS, H. N. C., ALLERSMA, E., and VAN DER WEIDE, J. 1968 (Oct). "Hydraulic Model Investigations in Dredging Practice," Proceedings, World Dredging Conference, WODCON II, pp 92-116.

Applications of models and modeling techniques to the dredging process, the stability of equipment, and to various natural areas or processes requiring dredging are the central themes. Advantages of models over prototypes are the ease of "surveyability" and handling, ease of observing, and better control of conditions. Less cost and shorter duration of experiments also are advantages. More complex systems require physical models, whereas mathematical solutions often are possible in relatively simple situations. Use of a model is possible only when, for all relevant phenomena, the relationship between the value of a magnitude in a model and its prototype value is known. Scale effects also must be known or tolerable. Among the topics covered in dealing with the dredging process are soil detachment/movement, head loss in suction pipes, cavitation and other phenomena in sand pumps, and phenomena in hoppers and pipeline systems. The section on equipment stability mostly covers the case of moored units, but also discusses design criteria for fixed objects; as a special case, floating and submerged pipelines are considered. Dredging in areas of different types of natural transport covers general dredging, work in rivers, and coastal and estaurine dredging. It is pointed out that a relatively new field is dredging of large channels and deep ports or pipeline trenches.

0918 BROOKE, M. 1958 (Jan). "Flow Formulas for Slurries," Chemical Engineering, Vol 5, No. 1, p 170.

Four formulas, along with nomenclature of terms used and applications or limitations, are given for slurry flows in several types of systems. For overflow from Dorr-type thickening tanks, two formulas are given coverning heads up to 0.03 feet and for heads from 0.07 to 1.0 feet. The remaining three formulas consider: (1) streamline flow of slurries in pipe, (2) friction loss of drilling fluid returning through the annulus, and (3) friction loss of drilling fluid through the inside of drill stem. The latter is noted as being applicable only to turbulent flow where the Reynolds number is between 60,000 and 300,000.

0919 BROUWER, L. E. J. 1973 (Aug). "Brouwer Explores Dredging's Future," World Dredging and Marine Construction, Vol 19, No. 10, pp 35-36.

Increasing demands in a number of areas are expected to have great impact on the future of dredging. After a slow start, dredging became an efficient and technological business in the late nineteenth century, with the advent of cutter suction dredgers and stationary suction hopper dredgers. Large capital projects were carried out early in this century. After 1950, there was a tremendous upsurge in the

legislature authorized $13 million for design and construction of an inland diked disposal area, with interim disposal continuing at two offshore areas. Environmental objections not only have slowed the process of approving a selected inland site, but are delaying to the point of hardship any necessary annual maintenance dredging until an inland site is prepared. Costs of inland disposal are increasing, and already have been as high as $7.70 per cubic yard, whereas offshore disposal has ranged from $1.42 to $2.25 per cubic yard. The site selected for diked disposal will erode in a few decades if not preserved by diking, and could later be used for recreation which is very much needed in the Baltimore urban area. Pressures are increasing from the site's owners to develop the area now as an industrial/commercial area. In the interim, "federal bureaucracies have bogged down Maryland's effort" to find a suitable dredged material disposal site.

0915 BRANS, T. 1979 (Sep). "Maintenance Dredging Demands Expertise; Experience," World Dredging and Marine Construction, Vol 15, No. 9, pp 25-28.

In modern times, physical phenomena such as erosion, sedimentation, or changes in river flow can be accurately predicted, and the needs for dredging, breakwater construction, or other changes can be estimated. Designers of projects involving dredging look for solutions to minimize undesirable erosion and sedimentation; for example, maintenance dredging in harbors sometimes is more viable and economical than capital costs to effect self-cleaning. The frequency of such dredging depends on whether or not a harbor experiences tidal influences. For estimation purposes, the type of material to be dredged, the depth, and the distance to the disposal area are equally important. Type of transportion available also has a bearing on cost and the type of dredging technique selected. A dredge not entirely suitable, but located very close and capable of performing the functions, can be cheaper and still be efficient. Payment for dredging is made in at least five ways, but the most reliable measurement for payment is "in the barge," that is, paying by unit volume just as in buying milk by the liter or steel by the ton. The types of items to be included in tender documents are reviewed. Two examples of maintenance dredging conclude the article.

0916 BRENNER, H. 1958 (Jul-Aug). "Dissipation of Energy Due to Solid Particles Suspended in a Viscous Liquid," The Physics of Fluids, Vol 1, No. 4, pp 338-346.

In comparison to energy dissipation in a homogeneous viscous fluid in laminar flow, a method is derived for calculating the additional mechanical energy dissipation as a result of the presence of solid particles suspended in the fluid. The development given is limited to certain flow conditions and also is valid only for mixtures in which particle dimensions are small in relation to the test apparatus. The technique is based primarily on a reciprocal theorem for inertialess flow of viscous fluids, and it allows calculation of the permanent pressure drop accompanying passage of liquid through a bed of

dissolve, settle, or agglomerate. The key items to be considered are the minimum velocity (below which particles settle from the liquid) and standard velocity (above which homogeneous flow takes place with particles uniformly dispersed). Derivation of equations for calculating critical velocities is demonstrated for various particle sizes. It was noted that further work needs to be done on small-particle systems even though empirical equations have been derived. For large-particle systems (pulverized coal or sand), the slurries must be handled in the heterogeneous region, and specific experimental data must be gathered. Pipe roughness is an extremely important factor in turbulent flow because of high shear stresses at the pipe wall. Most past turbulent flow data have been obtained in experiments using smooth stainless steel or brass pipes, and this does not yield realistic data. Pipe roughness has more effect at higher velocities. For any scaleup, the effect of roughness on each pipe size used should be determined.

0913 BOWEN, R. L., JR. 1961 (Sep). "Scaleup for Non-Newtonian Fluid Flow: Interpreting and Converting data," Chemical Engineering, Vol 68, pp 131-136.

This final part in a seven-part series on obtaining fluid flow data for pipeline design describes how to tell whether the material is a Bingham plastic, pseudoplastic, or dilatant fluid, and how to achieve good results from using a viscometer. It is noted that suspensions of solids in liquids very often behave as Newtonian fluids if the solids content is below 10 percent by weight. When a material does not have Newtonian characteristics, it is necessary to calculate rate of shear. Plotted data indicate the non-Newtonian material type by the slope of the curve. A new class of plastics is described as proposed by Casson. The means of converting data to laminar form are given, and discussions cover power-law fluids, Bingham plastics, and Casson fluids. Shear-stress values and use of an extrusion rheometer (capillary-tube viscometer) also are discussed in relation to obtaining appropriate data. The final parts of this section in the series discusses construction of viscometers and the differences in conventional rotational viscometers and the extrusion rheometer. For obtaining data by either instrument, it must be proved that the fluid is not time-dependent or otherwise anomalous. Absence of turbulence also must be assured or turbulence data must be collected from actual pipeline tests.

0914 BOYER, W. C. 1975 (Sep). "Dredging Has Become a Drudge," World Dredging and Marine Construction, Vol 11, No. 10, pp 68-71.

Dredging problems, primarily related to material disposal, are described for the Port of Baltimore, Maryland. Environmental considerations have played a significant part in deterring or delaying projects. Federal agency officials have repeatedly stated that they are not stopping needed dredging, but are objecting only to the method of disposal. In order to keep the port and waterways in first class shape, almost daily dredging has taken place for many decades, with open-water disposal in Chesapeake Bay at Kent Island Deep. On May 2, 1969, the Maryland

As the third part of a seven-part series on pipeline flow system design, this article considers turbulent flows. Several historical approaches to obtaining non-Newtonian turbulent flow data are reviewed; the main difference in the various approaches has been in defining the value of viscosity to be used in the conventional Reynolds number. Most early workers assumed that shear rates were high enough in turbulent flow to permit constancy in the viscosity. Several authors' data are shown to be in error, and it is pointed out that for some materials, turbulent flow data simply cannot be correlated on a single line. So far, no universal correlation of turbulent data has been obtained for all non-Newtonian fluids. For one reason, it is difficult to tell when and where turbulent starts with different pipe sizes. It is the opinion of the author that the large majority of non-Newtonian materials do not obey the power law, and that serious errors will be introduced by forcing the data to fit any type of power law equation. Existing methods of correlation of turbulent non-Newtonian data are applicable only to certain specific fluids that obey several special classic equations.

0911 BOWEN, R. L., JR. 1961 (Aug). "Scaleup for Non-Newtonian Fluid Flow: Best Methods for Obtaining Flow Data," Chemical Engineering, Vol 68, pp 119-122.

This article is one of a series about fluid flow studies, and concerns itself with methods of constructing extrusion rheometers (or capillary-tube viscometers) for obtaining laminar non-Newtonian flow data for system scaleup. Discussion is presented on how to accurately measure tube diameter, gage the system, and supply pressure in a noncommercial rheometer. One of the key precautions in using the device is to accurately measure and correct for (or control) temperature. Because data are for pipeline scaleup, it is necessary that data be collected over the range of temperatures to be expected. Even if the line temperature will fall to 40 degrees F or below only one day per year, the system should be designed for this, possibly by increasing normal pump horsepower. A comparative method of obtaining data is the use of pipeline tests, which must be used for turbulent flow data. In the rheometer, pressure is measured as a single gas pressure, whereas with the pipeline test, several fluid pressures must be measured, and several corrections must be made. It is highly suggested that when using an extrusion rheometer, it should be checked against a Newtonian fluid of known viscosity--perhaps obtained from the National Bureau of Standards in Washington, D. C.

0912 _________. 1961 (Aug). "Scaleup for Non-Newtonian Fluid Flow: How to Handle Slurries," Chemical Engineering, Vol 68, pp 129-132.

This article is Part 5 of a series dealing with pipeline flow and factors to be considered in scaleup design. One serious limitation to techniques presented in earlier parts is that, during fluid testing, there should be no irreversible physical or chemical changes in the fluids; polymers should not react chemically and suspensions should not

and, below a certain upward flow velocity, will have a clear liquid surface layer.

0908 BOWEN, I. G. 1961 (Jul). "Handling of Slurries," U. S. Patent No. 3,140,123.

Diagrams and detailed operational procedures are given for a device to handle slurries, which substantially minimizes the need to dispose of excess fluid (water). The device is limited to slurries defined as "solids in liquids, the stability of the suspension being such that deposition of the solid content does not occur quickly." The basic operation revolves around the principle that it is possible to discharge slurries against high pressure heads by means of "lock hoppers." A lock hopper is a vessel with a slurry inlet, clean pumping liquid inlet, dirty liquid outlet, and a slurry outlet (connected to a slurry pipeline). Separate valves control each inlet and outlet. The operation clarifies and recycles water by use of a thickener, and a battery of lock hoppers is used to maintain a continuous feed of slurry into the pipeline. In operation, a quantity of displacement liquid equal in volume to the volume of the solid content of the slurry is clarified and returned to the liquid source, and the remaining displacement fluid is conducted to the slurry reservoir.

0909 BOWEN, R. L., JR. 1961 (Jun). "Scaleup for Non-Newtonian Fluid Flow: Designing Laminar-Flow Systems," Chemical Engineering, Vol 68, pp 243-248.

This is the first article in a series which discusses obtaining data for pipeline scaleup when dealing with non-Newtonian fluids. A researcher in this field must be able to recognize material behaviors that do not conform to those of classic "pseudoplastic" or "Bingham" materials. After a brief review of definitions and examining differences among non-Newtonian fluids, a historial overview of pipeline design methods development is presented. Metzner and Reed produced the first general correlation for all non-Newtonian fluids using a modified conventional friction factor and Reynolds number plot; however, a long trial-and-error calculation is needed to get optimum pipe size. After reviewing works of several authors, it is shown that a new method can yield a flow diagram as well as a complete set of pipe/flow curves for various pipe sizes. The method of obtaining data is explained theoretically, and the need for using an extrusion rheometer to easily measure the necessary parameters is given. It is pointed out that the method does not work on time-dependent thixotropic fluids or rheopectic materials, and a scaleup treatment cannot be made. In some cases, even when a fluid is known to be independent of time, anomalous flow behavior may result; this sometimes happens with slurries.

0910 __________. 1961 (Jul). "Scaleup for Non-Newtonian Fluid Flow: Turbulent Flow--Historical Review," Chemical Engineering, Vol 68, pp 147-150.

New Corps of Engineers dredging criteria, put into effect in 1979, already are bringing about conflicts among State and Federal agencies in California. Among those involved are the Corps, U. S. Environmental Protection Agency, U. S. Fish and Wildlife Service, and a number of California agencies. In some cases, a single agency, perhaps one that only holds "commenting" ability on an applicant's proposed dredging, rather than "permitting" power, is the cause of extreme delays and a type of regulatory extortion. In the meantime, the applicants need permits and will do almost anything to prevent "rocking the boat" for fear of later agency reprisals. In October 1979, the California Port and Navigation Caucus was successful in providing California legislators, their aids, and agency officials with a first-hand look into regulatory problems facing the State's harbors. Follow-up actions and recommendations to solve problems are being studied.

0906 BOLLAY, W. 1941. "The Theory of Flow Through Centrifugal Pumps," Applied Mechanics, Theodore Von Karman Anniversary Volume, pp 273-284.

A detailed mathematical presentation is given for describing fluid flow through a centrifugal pump having radial or nearly radial impeller blades. The flow calculations are based on principles of the "theory of thin wings." The velocity components are calculated after a conformal transformation of n blades of an impeller into a single blade. The average radial velocity of the fluid (taken positive in the counterclockwise) is given as $V_r = Q/2pi \times r \times h$, where Q is the quantity of fluid flowing through the impeller per second, r is the radius, and h is the width of the impeller. The results and methods given are noted as also being applicable to the calculation of the "tip correction" in the theory of airplane propellers.

0907 BOND, A. W. 1959 (Mar). "The Behavior of Suspensions," Civil Engineering Transactions, The Institution of Engineers, Australia, Vol CE1, No. 1, pp 1-17.

This two-part article discusses theory and gives experimental data related to settling of suspensions (light flocculent particles) in still water and in an upflow. Alum and lime hydroxide flocs are the experimental materials. In each case, viscous drag of the fluid counteracts the action of gravity. Drag eventually balances with the force of gravity, and a particle settles with a uniform velocity. The well-known Stokes' Law is useful for calculating the settling velocity of spherical particles, but its use is not practical for evaluating individual particles in sedimentation basins. Among the topics rigorously covered are: settling and compaction of plastic particles, constant rate settling, hindered settling, relative velocities, concentration of solids, temperature effects on settling velocity, and results from setting studies on alum and lime slurries. Eleven different conclusions and observations are presented for the "still water" case. With regard to the case of "upflow," when particles have the property of coagulating with one another, the suspensions will exist as a unit, with clearly defined top

dredge. This arrangement could output 60 cubic meters of solids per hour working at 90 meters deep. Air requirements are 20 to 25 cubic meters per minute at compressor working pressure of 10 bars.

0903 BESPALOV, I. G. 1974 (Jul). "Use of Ejector Mud Intakes in Suction Dredges," Gidrotekh Stroit, No. 7, pp 16-17.

Testing of ejector mud intakes on suction dredges was made under a variety of depth and motor power conditions, usually in full-scale operations. The primary favorable features of using an injector are given as absence of cavitation, operation of the dredge without disruption to the vacuum, and easy freeing of the suction pipe from oversized soil inclusions. The three conclusions drawn are that: (1) the use of ejectors in the suction line increased the operating efficiency of dredges by increasing the excavation depth and eliminating losses of work time due to vacuum disruption; (2) up to a depth of 12 to 15 meters, the ejector for the ZGM-1-350A dredges with a discharge of 1280 to 1400 cubic meters per hour can be used economically with the 12NAS pump outfitted with a 100-kw, 1000-RPM motor at a discharge of 100 cubic meters per hour and a head of 24 meters; and (3) the use of ejector dredges for excavating severely boulder-clogged deposits of lakes is inefficient.

0904 BIJKER, E. W. 1973. "Future Developments in Dredging on Sea," Terra et Aqua, Vol 3, No. 4, pp 42-46.

This article begins with a very general introduction for future dredging at sea, but soon considers two major aspects: dredging for the very large cargo ships (500,000 deadweight tons, or larger) and what to do with the billion cubic yards of material produced. The channel and port requirements for the very large ships may be an additional 10 meters of depth, extra channel length (perhaps 20 kilometers longer), and changes in slope. The total quantity to be dredged to prepare a channel entrance for a 500,000 DWT ship will be about 420×10^6 m^3. With only half of a 1000-meter-wide channel to be deepened for such a ship, dredging cost would equal approximately the cost of one such ship. If 20 vessels of this type were built and used, dredging costs per ship cost go down. Prediction of maintenance dredging in such channels requires more study because the channels may influence the currents. Use of the dredged sand could be at inland sites, but probably would be better used for offshore airports, industrial sites, or for protective barriers. On islands built with dredged materials, industries unwelcome in the vicinity of cities could be placed. Much discussion is allotted to protection of islands and to innovative schemes of moving immense volumes of sand. Two such schemes involve a dredger separated from two floating trailing hoppers into which the dredger dumps, and a completely submerged dredger/hopper system (submarine hoppers). Visibility and inadequate echo sounding devices probably limit this latter suggestion.

0905 BOERGER, F. C. 1980 (Apr). "C-MANC Dredging Committee Protests Government Agency Obstacles," World Dredging and Marine Construction, Vol 14, No. 4, p 19.

Some areas like the Arctic are extremely sensitive, and rate of recovery is several orders of magnitude slower than in temperate climates. Canada also has an "Environmental Assessment and Review Process," instituted in 1974 by Cabinet directive. Policy on using foreign dredges in Canada is explained. No projects which would require large amounts of dredging are in the planning stage in Canada.

0901 BENDER, R. J. 1963 (Aug). "Long-Distance Fluids-Solids Pipeline Transportation Follows Logical Pattern," Power, Vol 7, No. 8, pp 68-69.

Hydraulic transport of coal as pipeline slurries has been ongoing for some time, but more recent planning includes pumping other substances, including iron ore concentrates, as slurries. This sounds appealing, but the high cost of components for handling, crushing, grinding, and processing of slurries is a problem. Another major problem of constructing workable slurry systems is the lack of reliable technical data. During design, equipment selection seems to be on an entirely empirical basis. In 1961, the Hydraulic Institute, an association of pump manufacturers, sought to shed light on fluid-solids engineering by sending out numerous questionnaires concerning six specific questions. Some of the questions were: (1) What minimum velocity is required in a 6-inch pipe to avoid solids settling when the concentration of solids varies? (2) How does friction rate in a 6-inch pipe vary when solids concentration increases? (3) What is the head loss of slurry as velocity increases? (4) What is the maximum concentration of a specific solid that can be transported by pipeline without undue difficulty? The answers to these and other questions are given, some in graphic form. The questionnaire replies revealed a wide scattering of data points and several apparent gaps.

0902 BERGEAUD, F. 1973 (Apr). "How to Calculate Air Lifts for Marine Dredging and Mining," Ocean Industry, Vol 8, No. 4, pp 169-171-173.

A new deep-water technique is described (and basic laws are derived) for using air lift to solve problems of dredging in narrow confines or at sea. The method is particularly applicable to cases which do not require dredging of large amounts of solids (1,000 cubic meters or more) per hour; in that situation, hydraulic jets may be used more efficiently. This simple method involves injection of compressed air at the base of a vertical pipe, which then mixes with the water/sediment and aids movement to the surface, increasing discharge height also. Among necessary considerations are working pressure, depth, air volume, and specific weight of the mixture. To a depth of about 50 meters, the height of discharge will be equal to approximately half the immersion. At greater depths, temperature, compressibility, and other factors come into play, thus bringing an extra gain to the discharge height. Two examples of application are given, one for sand/gravel mining and another for mining ocean bottom minerals. The latter example succinctly describes the vessel used, horsepower available, and an 8-inch suction

nondredging or nonpumping activities. These include weather forecasting difficulties, lengthy delays, and general time for access. The article concludes with a review of several specific problems encountered on projects of C. F. Bean, Inc.

0899 BECHLEY, J. 1975 (Sep). " 'Sandwick' Gives Nature a Boost on Shoal Removal," World Dredging and Marine Construction, Vol 11, No. 10, pp 37-41.

Directed propeller wash is one means of economically digging trenches or removing shoal areas. The Salvage Chief, a privately owned vessel with 1,800 horsepower per 55-inch-diameter propeller, was fitted with a deflector (22 by 20 feet) to enable it to trench up to 30 feet deep for installing pipelines. It operates in the surf and backs itself to the zero waterline while trenching. Using only propeller wash, it can dig a trench 75 feet wide and 20 to 30 feet deep along 1,000 feet of surf in 24 hours. The Corps of Engineers, Portland District, applied the same concept to shoal removal in rivers. An 18- by 12-foot deflector was installed on the Sandwick, which has 34-inch diameter propellers, each powered by 330 horsepower. The efficiency of this vessel in shoal removal was cheaper than paying nearly $7 per yard for jobs of less than 10,000 cubic yards. The Sandwick can effectively flush away shoaled mterial at a rate of 250 cubic yards per flushing hour by anchoring in one area for 15 minutes running propellers at full RPM, and then moving 20 or 30 feet and running again at full RPM. Unsuccessful attempts of the method occurred in swells of more than 2 or 3 feet or when coarse, heavy gravel was encountered. Success usually is limited to silt or sand in up to 20 feet of water. The Portland District is looking into applying the concept at greater depths by using shrouded propellers or a controlled, large-diameter hydraulic jet that could be lowered.

0900 BENCKHUYSEN, C. G. 1980 (Nov). "Dredging in Canada Is Complex; Diverse," World Dredging and Marine Construction, Vol 16, No. 11, pp 18-20.

The Canadian Government carries out dredging through six federal agencies, at about 2,000 sites--some annually, but most every 3 to 5 years. Of the six agencies, Public Works Canada is the only one that owns and operates its own dredge fleet. Although some projects are relatively large (for example, annual maintenance dredging of the Fraser River at 3.25 million cubic meters), Candian dredging requirements as a whole are small, many related only to pleasure craft use, or to maintenance of 11 national harbors. The Canadian Government exercises spending restraints. Free enterprise, however, often gets dredging contracts if competition in bidding is sufficient and if a clear description of the work is possible. Environmental related studies now are costing almost twice what dredging alone costs on the Canadian part of the Great Lakes. About 90 percent of Canada's population is in a 300-km-wide strip along the U. S. border, and only totals 24 million for all Canada. Canada has an "Ocean Dumping Control Act" which limits discharges at sea.

geology. Even small projects should include drilling of boreholes or at least using some type of probe. Probes, however, tell little about the material other than relative density. Boreholes should be done if costs can be justified, and a formula is given to project the general number of boreholes to be used on a grip pattern. Where geology is simple, fewer holes can be used. A table is provided for boreholes needed based on site dimensions. It is important to extract the maximum information from each hole; further in situ testing may be dictated. Soil investigation costs can be as high as over 25 percent of total project cost on dredging only 10,000 or 20,000 cubic yards, but may be below 1 percent on projects involving over 1 million cubic yards of dredging.

0897 BAUER, W. H. 1970 (Aug). "The Future of the Dredging Industry," World Dredging and Marine Construction, Vol 6, No. 10, pp 20-32-41.

This article contains excerpts of a speech by the president of the World Dredging Association. Current economic and social conditions are reviewed and related to the future of the industry, noted as being "the world's oldest." Man has always overcome crises, and the dredging industry will persist. Two words, "ecology" and "environment," are discussed as being newly discovered by the general public. Answers to the questions being raised regarding the effect of dredging on these newly found elements will have to be sought, and whatever adverse criticism arises must be overcome. The World Dredging Association, its benefits, studies, publications, and activities are reviewed. In a survey of 250 technical universities, out of 50 responses, 12 noted that some coursework pursued dredging subjects. However, only two schools had a positive program in dredging: Texas A&M University and Oregon State University. Also pointed out is the fact that the dredging industry generally has been lax in relations with public officials at every level, and that this must change to show that dredging is not the "villain that some would have him believe."

0898 BEAN, J. 1973 (Jun). "Offshore Dredging Problems," Report No. TAMU-SG-73-102, CDS-149, Texas A&M University, Center for Dredging Studies, College Station, Tex.

An overview is presented on future dredging of increasingly larger offshore projects. This situation is compared to that of the oil industry 20 years earlier. Three new major types of engineering projects are gaining momentum: offshore terminals, offshore airports, and beach nourishment projects. Dredging functions remain the same, but the environment for work has changed; more operations are required to take place in rough water. The successful offshore dredger must solve the two problems of stabilizing the dredging platform and maintaining pipeline integrity. Three possibilities are discussed for stabilization: larger hulls, direct ocean floor attachment, and computer-operated thruster systems (for the "true advanturer"). Several solutions to pipeline integrity are mentioned, including development of floating rubber hoses. Other problems concerning offshore dredging relate to

of the pipe), sliding-bed flow (particles move along the bottom by saltation, or along the top in this case using ice with lower density than water), stationary-bed flow (solids settle out permanently and plugging can occur if concentration is high), and compaction flow (at high concentration, solids contact, adhere, and flow as a coherent plug, separated from the pipe wall by a film of liquid phase). A derivation of formulas and comparison to slurry flows are made. Slurry correlations do not apply to slush flow for two reasons: (1) slush particles do not contact pipe walls significantly long because frictional energy dissipated causes wetting of solid phase, and (2) density ratios for the solid phase in a slush flow is always in the range of 0.90 to 1.30; slurries may involve a much wider range of ratios. A test device is described using transparent pipes and a camera system. The compaction flow regime was noted as a characteristic of slush flow but not of slurry flow.

0895 BASKETTE, C. W., JR. 1975 (May). "Maintenance Dredging Restores Virginia Beaches," World Dredging and Marine Construction, Vol 11, No. 6, pp 48-52.

An operation is described which uses unpolluted sand from a portion of the maintenance dredging of the Thimble Shoal Navigation Channel to nourish 3.3 miles of eroded beaches at Virginia Beach, Virginia. In the past, sand has been obtained from inland and estuarine borrow areas, but these supplies are being depleted and costs are becoming prohibitive. In this project, sand from maintenance dredging could not be placed directly on the beach that needed it (because offshore water was too shallow to moor the dredger). Instead, sand was stockpiled in a temporary storage area at Cape Henry (where beaches are 500 feet wide) along a 2,500-foot stretch. Material was dredged by the hopper dredge Goethals, moved nearshore at Cape Henry where a special mooring barge was attached to a DeLong Pier, and pumped ashore through 1,100 feet of submerged line (28-inch inside diameter, 5/8 inch thick) and to the stockpile area through another 2,700 feet of 28-inch pipe. A total of 452,000 cubic yards of sand was stockpiled between October 6 and November 15, 1974. When weather was such that sand could not be stockpiled, the dredge continued to move unwanted material to an ocean dumping site 16 miles away. Cost of stockpiling the sand by dredge was $0.93 per cubic yard, but trucking the sand to its final destination escalated the price to $2.58 per cubic yard, competitive with direct hydraulic pumping.

0896 BATES, A. D. 1981 (Apr). "Profit or Loss Pivot on Pre-Dredging Surveys," Dredging and Port Construction, Series 2, Vol 8, No. 4.

Gaps in knowledge of soils have severe effects on dredging. In excess of 50 percent of dredging works exceed their budgets, and the biggest single causative factor is inadequate soils knowledge. Knowledge of soil type, depth, and extent determines the choice of dredging plant and other considerations. A preliminary investigation for a project should always be made: gathering existing information (at a minimum), defining site limits, and obtaining a general picture of site

The study described herein is a follow-up to a nearly identical series of tests on mill tailings from a Montana mine. Testing data were obtained on friction-head losses of a number of slurries composed of barite and limestone fragments of various particle size and at different densities (40 to 80 percent solids). The two materials were chosen because of their different specific gravities. All testing was at a pilot plant in short lengths of horizontal piping of three different diameters (2-, 3-, and 4-inch). Because of mechanical problems, the bulk of testing utilized the 3-inch pipe. Limestone testing resulted in 495 measurements at flow velocities from 6 to 14 feet per second; barite tests (640) were made only in 3- and 4-inch pipes and the same range of flow velocities. The friction-head losses derived from testing were within reasonable limits of accuracy for loss estimates in plant designs; however, it was cautioned that applying the results to long pipeline sections necessary for mining operations may be undesirable. Barite data were slightly more erratic than data for limestone.

0893 BARKER, J. V. 1969 (Jun). "The PACECO Jet Stream System," World Dredging and Marine Construction, Vol 5, No. 5, pp 28-30.

The addition of a high-pressure jet pump in the suction end of a hydraulic dredge ladder has permitted sand dredging of 200 cubic yards per hour at a depth of 200 feet for placement of a dam foundation. With this success, PACECO applied the concept to dredges to boost production at normal depths. The system supplies a specific volume of water at a given pressure through nozzles in the direction of the suction stream; the device is completely protected in that no moving parts are in contact with the solids. By providing a "flooded suction" to the dredge pump, higher speeds can be obtained without cavitation, producing more solids, more flow, and higher heads; higher velocities permit longer discharge lines. Each system is more or less custom designed, but in general, a jet stream system designed to produce 30 percent solids at a 50-foot depth is 2.5 times more productive than the dredge without the jet stream. Capacity of the same dredge with a jet stream system designed for 40 percent solids at the same 50-foot depth is increased to 3 times normal output. The jet stream system is applicable to a cutterless sand-sucker, a cutter head pipeline dredge, a rotating suction pipe dredge, or a side dragarm hopper dredge. It can be used as an eductor without a pump to raise heavy sand and gravel to hopper dredges from as deep as 140 feet.

0894 BARRON, R. F. and FAIRCHILD, P. D. 1969 (Nov). "Two Phase (Solid-Liquid) Flow Regimes," Paper No. 69-WA/FE-33, ASME.

A study of two-phase, single-component flow is described. This type of system is termed a "slush" in contrast to a "slurry," which is a two-phase system, but with two different thermodynamic components, such as sand and water. The slush used was water and 1/8-inch ice particles. Observations were made to determine the flow regimes, that is, in order of decreasing bulk velocity: homogeneous flow (uniform distribution), heterogeneous flow (nonuniform, but not limited to one area

This article describes engineering and logistical features of an immense dredging job in which sand (12 million cubic yards) from the bottom off Staten Island is being moved over 9 miles to act as surcharge for a 325-acre marshy tract to be used for additional Newwark airport facilities. Two dredges are being used; one to act as a suction dredge, and the other only to pump the hydraulic fill from 1.5 miles offshore to the fill site. In between (8 miles), the fill is initially loaded in scows (two abreast) and then towed by tugs to a slotted mooring device, consisting of a converted railroad car float and the second dredge. All pipes are 27-inch diameter and are floated on flexible pontoon arrangements at the dredging site. The fill is only 10 percent solids, and water overflows the scows until they are full. At the pumping dredge, the fill is mixed again with water from two high pressure jets before being pumped by a 5,000 horsepower General Electric motor and a pump with a 96-inch impeller. Special precautions are taken at the fill site for mobility of the pipe sections, maintaining correct elevations, and preventing valve freezing. Operations continue on a 24-hour basis with multiple sets of scows, five tugboats, and several Caterpillar tractors at the fill site. Total project cost is $12.4 million.

0925 BURE, H. 1971 (Apr). "Clean Water Through Dredging," World Dredging and Marine Construction, Vol 7, No. 6, pp 20-24.

The effects (both adverse and beneficial) of dredging on water pollution are discussed in response to the dredging industry being considered villains when the topics of "environment" and "ecology" are mentioned. The broad definition of water pollution used herein is "any change which affects the practical condition of the water adversely for any purpose." The author makes the point that dredging, as a technique, is one of the very few, if not the only, available means to reduce or avoid certain types of water pollution. This is substantiated by descriptions of how dredging improves various types of water pollution, from toxic materials to high BOD, and from suspended solids to distasteful aesthetic conditions. It is pointed out that dredging itself does not create or cause toxic spills, that it can be used to pick up silt or high BOD materials, and that by increasing river cross-sections, flow may be reduced and allow less turbid conditions. The poorly designed, inefficient dredge is blamed for some past problems. Encouragement is given to improve on the technical, promotional, legislative, and supervisory aspects of dredging, but the key to the pollution issue is to provide improved methods and equipment in the dredge industry in order to run more efficient operations with a higher level of management and skill.

0926 BURTON, B. and KOLBERT, L. 1975 (Mar). "Production Meter System--Aid for Suction Dredges," World Dredging and Marine Construction, Vol 11, No. 4, pp 30-31.

The advantages of using a production meter system in dredging are explained. It is seldom possible for the lever man of a suction dredge to maximize production rates with only manometers and a pump tachometer

as indicators of dredge performance; however, a production meter system indicates solids flow rate (production rate) in such a way as to guide toward maximum production under any operating conditions. The system consists typically of a magnetic flow meter to sense flow velocity, a density gauge (in this case, a gamma radiation detector which gives a signal proportional to density or solids content of the slurry), an electronic module to compute production rate and total production, and indicators of flow velocity, solids content, and production. Each component and its application is described. Panel meters with pointers are suggested as the most practical indicators (as opposed to digital meters) because they can simultaneously show rates, direction, and trends of measurement. A "cross-pointer" system is explained in which one pointer indicates flow velocity and a second shows solids content. The crossing of the pointers, read against a family of parallel curves on the meter face, indicates production rate. By watching this single display, the lever man can see how trade-offs between density and velocity affect production.

0927 BUSSEMAKER, O. 1968 (Oct). "Schottel Units for the Propulsion and Maneuvering of Dredging Material and the Dynamic Positioning of Offshore Equipment," Proceedings, World Dredging Conference, WODCON II, pp 117-169.

A variety of right-angle drive propulsion systems and thrusters manufactured by Schottel are described and pictured. Many advantages of highly versatile right-angle systems are put forth, and maneuverability in critical situations is one of the key advantages. Among the topics covered in discussing design philosophy are available power, propeller diameter, gear reduction, gear dimensions and strength, propeller torque, mechanical power losses, and transmission housing. Two of the features which make these right-angle systems advantageous are the ability to swing the units entirely free of the water and to make vertical depth adjustments. Efficiency of the Schottel Rudder propeller systems is discussed in some detail, and the article concludes with a brief history of Schottel equipment applications and numerous examples of equipment installations. Among the types of dredging equipment for which these systems have been designed are hopper barges, cutter suction dredgers, grab dredgers, floating cranes, stone dump barges, and the so-called "hydro pump omnibarges." A total of 4 data tables and 23 figures support the text.

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0928 CAMPBELL, P. I. 1976 (Mar). "Electronic Devices Aid in Discharge Measuring," World Dredging and Marine Construction, Vol 12, No. 4, pp 32-36.

The Water Resources Branch, Environment Canada, attempted to improve its hydrometric surveys by improving accuracy, reducing manpower requirements, and making observations not possible previously. Because the measurement of discharge was the least automated and offered the most potential for improvement, emphasis was placed on this parameter. For large rivers, the most improvement was needed in measuring horizontal distances, particularly from moving boats. Sextants and a variety of electronic distance measuring devices were found to require an almost stationary platform, a condition seldom achievable on the rivers. An instrument introduced in 1970, and designated the MRB201 Tellurometer, was capable of providing distance measurements accurate to about ±1 meter from a moving platform, or about 0.5 meter from a static station. Setup time is rapid. Conventional methodology required 7 hours, whereas use of the Tellurometer required only 1.5 hours on the St. Lawrence River. The device is described in detail (eight separate components). Several new improvements being field tested also are discussed. These include means of preventing signal interruption and addition of a cost efficient microcomputer to carry out calculations and regulate a cathode ray display.

0929 CARGILE, N. H. 1972 (Nov). "New Tool Born to Restore Dead Lake," World Dredging and Marine Construction, Vol 8, No. 12, pp 40-41.

An AMMCO portable dredge with a new type of rotary chopping wheel was used to restore a dead lake in which no water was visible and which was completely overgrown by vegetation. The lake eventually was dredged to a 10-foot depth. Initially, vegetation was cut and moved into "windrows." Then, water was pumped into an area (hole) dug by draglines, which was just large enough for the dredge to operate and maneuver. As the lake became larger, pumping of water was discontinued, and underground springs supplied clear water. The rotary chopping wheel added to the dredge worked as a "wood chipper," cutting stumps, logs, roots, or other vegetation into small pieces, directed by a special guard cover into the dredge pump. The water/vegetation mixture was pumped through 5,000 feet of discharge line to a slightly elevated diked area between two hills. Pumping rate was 200 cubic yards per hour. The pump impeller also was fitted with a special knife to keep it free of debris. This method virtually eliminated downtime, and the operating cost was between 15 and 25 cents per cubic yard. Blades in the wheel had to be changed once per week, requiring about one hour.

0930 CASHIN, J. A. 1956 (Nov). "Density of Spoil in Suction Dredging," Dock and Harbour Authority, Vol 37, No. 433, pp 232-235.

Initial development is described for a device that gives suction dredge operators an immediate indication of density of pumped material. An inlet area in New Zealand contained extremely fine materials which needed frequent removal. The "dry hopper" dredge Canterbury had operated for many years inefficiently removing the material. The dredge is of the type that, once the hopper is full (whether with sediment or sea water), must be pumped out before dredging can again commence. The dredge's capacity is 30,000 cubic feet. It was designed to be filled with material of specific gravity 1.45 from bed material of specific gravity 1.68, with the 1,200 tons of mixture containing 900 tons of sediment and 300 tons of water. Because the operator could only read cutter depth and vacuum in suction pipes, material pumped was often too thin. Many times, the material had to be diverted overboard. There was a great need for ability to read directly and continuously the density of the pumped mixture. Weighing methods and strain-gage deflection devices were investigated, but neither worked. Eventually, the idea of projecting X-rays (gamma source of cesium 137) through the discharge side of the pumping pipeline, and its detection and conversion to a 20-second integrated readout, was developed. The idea was converted to reality by the Canterbury New Zealand University Industrial Development Department.

0931 CHARPENTIER, J. J. 1970 (Oct). "The Use of Explosives in Dredging," Work Boat, Vol 27, No. 10, p 29.

Explosives are one of man's principal tools, the most powerful by far, and can be used safely and sufficiently controlled for a variety of underwater construction needs. With explosives, savings of up to 70 percent can be realized on some projects in comparison to previously used methods. Because of the increasing need to provide deeper ports and channels for deep-draft vessels, explosives can fragment rock sea bottoms to sizes removable by conventional dredges. Other explosives applications developed for underwater use include explosive cutters capable of cutting steel up to 2.5 inches thick. This method can be used to remove oil industry platforms by butting them off below the sea floor to leave bottoms clean. Another device operates explosively underwater to cut off the flow of a wild oil well and extinquish a fire. Meanwhile, spilled oil can be contained quickly. Many of the explosive methods now used are not only safe, easily transportable, inexpensive, and meet international regulations, but they can be controlled to prevent fish kills.

0932 CHATLEY, H. 1940 (Mar). "The Pumping of Granular Solids in Fluid Suspensions," Engineering, pp 230-231.

Power efficiencies are discussed with respect to vertical and horizontal transports of solids in fluid suspension (primarily grain in air). A brief review of past work reveals that problems involved with horizontal transport are more obscure because the solid-phase suspension is due to vertical components of the "secondary turbulent currents." Six elements of power consumption include: (1) lifting solid grains

(for horizontal pipes, this is zero); (2) accelerating the grains (providing their kinetic energy); (3) sustaining the grains in the mixture and overcoming friction against pipe walls; (4) accelerating the fluid; (5) overcoming fluid friction; and (6) compensating for loss of kinetic energy at bends, valves, etc. Calculation examples are shown for all of these elements of power consumption. It is shown that compensating for bends is one of the biggest problems. Bends should be eliminated as much as possible. With hydraulic conveyance, terminal velocities are much smaller in water than air because water is 800 times as dense. Hydraulic conveyance efficiency is much more economical than pneumatic conveyance, and is highly suggested for materials not injured by wetting, but proper proportioning between solid and fluid phases must be done.

0933 CHATLEY, H. 1949 (May). "Dredging Problems and Soil Mechanics," Dock and Harbour Authority, pp 7-8.

The field of soil mechanics has something to offer practical engineers in the dredging business because many problems encountered in dredging are interrelated to those of soils in general. This paper discusses aspects of soil mechanics as related to seven items: (1) the bulking of disturbed sediments (or the relation of "barge measure" to "in situ" volumes); (2) the dilution of material pumped in suction dredging; (3) settlement of materials in hoppers and spoil basins; (4) shearing strength of submarine materials and their resistance to cutting; (5) energy requirements for breaking up a consolidated sediment (paste) into a fluid suspension; (6) the stability of submarine banks of silt and sand (submarine "slides" or subsidence); and (7) conditions of erosion and accretion. The "void ratio" is discussed as an important factor which is a measure of the degree of packing (varying from 0 for solid rock to perhaps 20 for an aqueous jellylike sediment). Soil mechanics is especially applicable to studies of lateral subsidence because accurate information helps determine the amount of re-dredging that may be necessary to maintain deep bottoms.

0934 CHURCH, A. H. 1944. Centrifugal Pumps and Blowers, Wiley, New York, Eighth Printing, March 1960.

Today, the application and use of centrifugal pumps and blowers are universal. Utilities, chemical plants, and numerous other works would be seriously handicapped without them. This book is written for young engineers who must deal with such equipment. No new theories or advanced designs are put forth; instead, the basic principles of design, construction, and application are covered. Numerous examples and problems with answers accompany the text for clarification. Sections in the book cover the principles of fluid flow and thermodynamics, as well as basic theory of pump and blower operations. Those sections specifically related to pumps discuss specific speed and efficiency, performance curves, cavitation, design of radial-type pumps, pump impeller types, other pump components, pump applications/selection, and pump installation, operation, and testing. Major topics related to blowers are

classification and performance curves, design of radial-type blowers, construction details, blower applications, regulations, installation, operation, and testing. Risk stresses and critical speeds are discussed in separate chapters. Economic considerations are emphasized throughout the discussions, where appropriate.

0935 CLEVELAND, N. 1971 (May). "Concepts for Deep Ocean Mining," World Dredging and Marine Construction, Vol 7, No. 6, pp 32-35.

Different types of inland and marine dredges, and their onboard equipment, are evaluated in relation to use for mining. Such high specific gravity materials as gold, platinum, tin, and diamonds are considered. The conventional bucket line fails to provide satisfactory deep mining results. Cutter suction dredges have been used for over 50 years and are far less costly; thus, it appears desirable to develop such dredges for offshore mining. Because suction dredges take up lighter particles first and classify and sort the material in fringe areas, they should be used mostly to recover minerals with relatively low specific gravity. An altered means of bucket line dredging is suggested for deep and valuable offshore deposits. Stability in high waves is assessed, along with the vulnerability of conventional design digging ladders and their tendency to "plunge" into the digging face in heavy seas. Several radical departures from the conventional ladder designs are suggested. One incorporates the use of a large dredge's hull as the ladder and uses modified dragline buckets (widely spaced on paired cables). The advantages and disadvantages of this system are compared, along with an in-depth treatment of onboard material sorting devices. The jig is given most emphasis because it functions to concentrate, size, and dewater the material.

0936 __________. 1978 (Aug). "More Tin at Lower Costs," World Dredging and Marine Construction, Vol 14, No. 8, pp 36-37.

When dredge mining for tin, which is done primarily in Malaysia, the world's dredge mining center, serious problems in wastage occur, often more than 10 percent of a dredge's production. The cause of the wastage is discussed in relation to onboard equipment, the presence of much "jungle trash" (basically, waterlogged vegetation), and the density of suspended solids (often a high-value suspension). The top 15 feet or more of the dredge ponds are virtually "slimes." Deeper layers are more dense. One example shows that a 4-inch casing pipe would only sink to 65 feet by its own weight in a pond 150 feet deep. Thus, much highly valuable tin was suspended. One method to keep dense suspensions removed from the ponds, and thereby allow digging buckets to pick up high-density particles, is to use a "mud pump" and floating pipeline to pump the material completely away from the pond. Past efforts to use mud pumps were thwarted by clogging from the "jungle trash," but submersible dredge pumps recently have benefited. Clear water in the ponds not only allows heavier, recoverable particles to settle, but reduces power consumption needed to swing the dredge and aids wear duration on submerged dredge parts.

0937 CONDOLIOS, E., CHAPUS, E. E., and CONSTANS, J. A. 1967 (May). "New Trends in Solids Pipelines," Chemical Engineering, Vol 74, No. 10, pp 131-138.

Instances of using pipelines for long-distance transportation are very few; however, many short to medium length lines are in use to deal with problems almost unsolvable by conventional methods. Advantages of using pipelines are that they can handle enormous capacity with a minimum of installation space, they are extremely flexible with respect to layout and use of elbows to change vertical or horizontal direction, they can have a high degree of automation and also keep power costs to a minimum, and they are the most economical in terms of capital investment. The disadvantages include the fact that once a system is designed for a certain solid-fluid mixture, it may not be suitable for pumping anything else. Furthermore, the solid to be transported must not suffer from being wet and the drying process (if necessary) must be expedient. After reviewing flow laws for solids in pipes and discussing "homogeneous slurries" and "heterogeneous mixtures," the article describes eight pipeline systems used for transportation of coal, mine tailings, fly ash, nickel slag, gunpowder (in sticks), uranium ore, and diamond-bearing gravel. The final consideration is a transportation mode using solids packed in containers, which are then transported via a fluid-filled pipeline.

0938 CONDOLIOS, E., COURATIN, P., and CHAPUS, E. E. 1963 (Mar). "Pumping Ores up Vertical Shafts," Canadian Mining and Metallurgical Bulletin, Vol 66, pp 187-198.

The principle of hydraulic transportation has very rarely been applied to hoisting material to any significant height. Hydraulic hoisting, however, offers several advantages over conventional methods. Among these are small shaft space requirements, flexibility in layout, and relatively low investment and operating costs (including labor). In most cases, a vertical hoisting pipeline will be preceded or followed by a horizontal section, which complicates overall design considerations. After discussing general characteristics of mixtures in vertical and horizontal flow, specific mathematical relationships are given for transport concentration, lag coefficient, fall velocity, head loss, and power requirements. The efficiency of a hydraulic hoist system depends ultimately on the density and mean fall velocity of the solid in a certain medium, the density of the fluid phase, the solid discharge, the transport concentration, and the pipeline characteristics (diameter, roughness). The "lock feed system" is used to feed materials into a pipe at high pressure and needs to be designed for more or less continuous flow. Use of the lock feed mechanism in a vertical system eliminates the need for the pumped solid to pass through the pump, and energy consumption is reduced. One example of a large vertical transport system for coal is given.

0939 CONDOLIOS, E., COURATIN, P., and PARISET, E. 1961 (Jun). "Transportation of Solids in Conduits, Industrial Application Possibilities, Engineering Journal, Vol 44, No. 6, pp 62-66.

Hydraulic transport has greatly improved in the last few decades, more out of technical necessity than a determined desire to use it. A number of theoretical considerations are discussed as related to particle size and the nature of homogeneous or heterogeneous mixtures. If grains are fine (less than 0.2-mm diameter) and flow viscosity is high, the solid phase is nearly always in suspension. If materials are larger than 2 mm or velocity is slow, transportation is primarily by saltation. Power requirements for horizontal transport must be calculated on a case-by-case basis, but some general rules apply when considering energy input per unit weight transported: (1) the input decreases with concentration of materials introduced into the flow, (2) it is very sensitive to deviations in material grain size, and (3) it is a function of the apparent density in the transporting fluid. Values of power use are given for moving 100 tons per hour of materials of equal density: gravel larger than 2-mm diameter requires about 6 horsepower per ton mile, whereas sand (with a mean diameter of 0.4 mm) requires 2.2 horsepower per ton mile. Conduit dimensions are discussed in relation to preventing jamming and for stable system operations. Three installation concepts (and three special cases) are the gravity installation, those with pumps with material not passing through the pumps, and those with pumps through which the materials pass. A number of examples are described. An economic evaluation concludes the article with discussions of equipment amortization, energy, upkeep, and labor requirements.

0940 COOPER, H. R. 1973 (Jun). "Catamarans Aid in Dredging Field," World Dredging and Marine Construction, Vol 9, No. 8, pp 31-32.

Catamarans are beginning to gain popularity because of their potential to perform a number of functions in the dredging field. Because of their shallow draft, and with special design of pontoons, catamarans only roll about 12 degrees, in comparison to an estimated 24-degree roll of a monohulled vessel of similar size. Catamarans provide maximum stability, ample deck space, spacious engine rooms, and excellent maneuverability. For dredging applications, this type vessel is ideal for initial dredging preparation such as serving as a drilling rig, a sounding platform, and for laying anchors for a bucket dredger or cutter suction dredger. The twin hull design also may be adapted to be one of several types of dredger. The largest vessel of the catamaran type operating in European waters (the Duplus) is described; it is 128 feet long, with a beam of 54 feet. The ship is used for making wave measurements, taking soundings, laying pipelines, and for supplying drilling platforms and other structures on the continental shelf. Other catamarans are being designed for future service in similar operations.

0941 COPLAND, G. V. 1960 (Jun). "Development of a Continuous Fluid Density Measuring Device," Paper No. 60-SA-20, ASME.

A hollow-beam type density meter for use on water-cement slurries has been developed, tested, improved, and proven in the field. Five types of measurement systems used to quickly measure fluid densities have not worked with water-cement slurries for a variety of reasons,

ranging from buildup and clogging to slow response time or cost. The desirable features sought for a water-cement mixture are: (1) readout must be dependent directly on the fluid and material density, (2) sampling should be continuous and representative, (3) measurement should be recorded and have a minimum time lag, (4) the instrument must be rugged and low cost for field use, and (5) it must be cleaned easily. One instrument type is described from its inception through several models in which improvements are incorporated. The instrument consists of a pipe loop arranged as a beam scale, supported on pivots and connected to a pneumatic weighing system. When a given sample passes through the loop, density is indicated in 1 second. About 0.5 horsepower is needed to force fluid through the loop at 10 gallons per minute. A differential pressure transmitter was used as the initial weight sensor. Original accuracy limits set for the instrument was for ±1 percent hysteresis, and linearity of response. Several improvements to the instrument, and their rationale, are elucidated.

0942 CORPER, M. 1969 (May). "Dutch Expertise in Dredging Equipment," Dock and Harbour Authority, Vol 50, No. 583, pp 32-34.

Holland's economy and existence have depended on holding back the sea, and it is the Dutch that have achieved prominence in development of dredging methods and equipment. The history of Dutch dredging goes back over 400 years to when the Amsterdam "mud mill" was evolved, the forerunner of the familiar bucket dredger. Steam engines in the 1800's gave another boost to dredging, and a host of dredgers were developed in the early 1900's: suction and cutter suction types, rock-breakers, grab and dipper types, and trailing suction hopper dredges, the first of which was delivered in 1911. In 1945, steam suction dredgers with pumps had a total of 1,000 horsepower. In just 20 years, that has increased to where one trailing dredger has an installed capacity of 21,500 horsepower; it also has a capacity of 9,000 cubic meters, and can dump 18,000 tons of spoil in 5 minutes. "Mini-dredgers" and a variety of specially designed dredges also have been built by Dutch companies. Four tables of data are presented which give characteristics of bucket dredgers and suction dredgers, and how the number and value of these types have changed. The final table shows how capacity of different dredge types have changed from 1938 to 1968, by 10-year increments. Dredging equipment is of significant export value to Holland.

0943 COSTANTINI, R. 1961 (Aug). "Pipelines Show Good Potential for Long-Distance Transporting of Solids," Mining Engineering, Vol 13, No. 8, pp 977-981.

Long-distance hydraulic transportation by pipelines is providing economic benefits, especially in the mineral processing industries. The key to practicability is availability of a large amount or raw material that is already, or easily can be, reduced to a slurry of fine particles. However, the theoretical and experimental knowledge for full evaluation of factors in the slurry flow process is far from complete, and much additional research is needed. Two long-distance pipelines are operating,

one moving 700 tons per day of gilsonite from a mine at Bonanza, Utah, 72 miles to Grand Junction, Colorado. The other is the largest, a 108-mile long, 10-inch-diameter line moving 4,000 tons per day of coal slurry from Cadiz, Ohio, to the Eastlake Power Plant. Few other projects longer than 10 miles exist or are in the planning stages. A number of planned projects are described, including more work on coal pipelines and phosphate fertilizer transport. Economic and technical factors are explained in designing and operating slurry pipeline systems. The influence of particle size and of pipe size on velocity are given special emphasis.

0944 CRAVEN, J. P. 1951. A Study of the Transportation of Sand in Pipes, Ph. D. Dissertation, Iowa State University, Ames, Iowa.

A pipeline system design must ensure that hydraulic conditions permit maximum discharge under the worst expected conditions of sediment transport and deposition; unfortunately, criteria upon which proper design must be based are undetermined. The purpose of this study is to determine the most important parameters which control the hydraulic gradient and geometry of deposited sediments, and to evaluate their effects experimentally. Although independent variation of at least six variables is involved, the only variables which could be independently controlled during these studies over a continuous range of values were: (1) volume rate of fluid discharge (Q), (2) volume rate of sediment discharge (Qs), and (3) slope of the pipe(s). Variation of pipe diameter was controllable, but only two pipe diameters were used, 2.00 inches and 5.55 inches (inside diameter). Transport phenomena of sand in pipes show three distinct regions: (1) a region in which the piezometric gradient is governed by the transport discharge ratio Qs/Q, (2) a transition region, and (3) a region in which piezometric gradient is independent of Qs/Q and dependent upon the properties of the flow, roughness of the boundary, and critical shear of the sand. Equations describing each of these regions are presented in the conclusions; however, it is noted that values of the numerical constants in the equations are dependent upon an undetermined parameter involving the properties of sand, primarily more noticeable for small-grained sand.

0945 CRUICKSHANK, M. J. 1963. "Mining Offshore Alluvials," Proceedings, Symposium on Opencast Mining, Quarrying and Alluvial Mining, Institution of Mining and Metallurgy, pp 125-155.

Alluvials are unconsolidated deposits of minerals which primarily are found on the extensive continental shelves of the world at depths generally from 0 to 600 feet (average is 432 feet). In the Americas alone, the shelf covers about 3.7 million square miles. With a few exceptions, exploration methods are similar to land-based methods, but other aids are used such as reflectance surveys (sub-bottom profiles), television, and photography. Among the types of dredging apparatus used to mine offshore alluvials are bucket ladder dredges, draglines, clamshells, hydraulic suction dredges, and airlifts. Each of these is good for particular types of mining; for example, bucket ladder dredges are

used for river or placer deposits in relatively calm waters where the depth requirements can reach 100 to 150 feet. Draglines and clamshells are excellent deep-sea sampling devices, but for offshore mining, they are particularly efficient only in recovery of beach sands. Hydraulic dredges mainly are confined to use in removing overburden or mining unconsolidated sand or gravel. Airlifts are simple to make and operate and produce considerabe lift and volume. This is one method chosen for offshore diamond mining, which, when problems are minimal, can recover 700 carats per day of gems worth $35,000 on an operating and overhead cost of $7,000 per day. In addition to discussing several examples of offshore mining, and the equipment used, the author presents a number of tables giving data on mining dredges and worldwide offshore operations. Maps, offshore deposit locations, and values also are given.

0946 CUNNINGHAM, R. G., HANSON, A. G., and NA, T. Y. 1970 (Sep). "Jet Pump Cavitation," Journal of Basic Engineering, Series D, Vol 92, No. 3, pp 483-494.

A most important problem in the design of liquid jet pump systems is the ability to predict the onset of cavitation, which may be induced in such a pump by increased velocity of the primary pump, decreased suction port pressure, or decreased delivery pressure. Incipient cavitation has no effect on jet pump efficiency, but severe conditions can cause a spreading to the walls. This article summarizes previous works (14) on jet pump cavitation and the relationships among these parameters, compares experimental data for three jet pump R values (nozzle-to-throat area ratios), and develops a limiting-flow prediction equation and discusses its value in jet pump design. Cavitation prediction parameters in the past have often included the effect of vapor pressure; these parameters and their relations are discussed in detail. Other parameters also are discussed with the ultimate intent of a "best single-number parameter" for correlating jet pump cavitation data. Of 14 data sets, 11 show adequate representation by a single number for a "cavitation index." The value 1.35 is recommended for conservative use, although the range given is 1.0 to 1.4. A limiting flow function Y is shown to be a useful tool in comparing cavitation response to design changes.

0947 CUSHING, J. F. 1930 (Nov). "Economical Design of Hydraulic Pipeline Dredge," ASCE, Papers and Discussions, Vol 56, pp 1971-1996.

One of the largest and most powerful dredges built to date is described, as designed by the Great Lakes Dredge and Dock Company. Among the dredge's unusual features are an extremely heavy and rigid hull to withstand vibrations and support the dredge, a cutter drive of great flexibility, and a diesel-electric power plant. A gyro-compass also is a unique feature, allowing accurate positioning in heavy fog or if forced to leave a site and return (e.g., after a storm). The purpose of such design is to minimize costs of capital, labor, and power. Among the most important conclusions are: (1) a dredge with a 30-inch diameter discharge pipe is more economical than any small size, (2) a diesel-electric power plant results in lower production costs than a direct

diesel drive, and (3) a single-stage dredge pump driven by the maximum power applicable is most desirable. The article discusses in some detail various aspects of power plants, physical characteristics of clay and shale deposits, and a number of design elements, such as the hull, deck house, crew quarters, cutter ladder, suction and discharge pipes, pumps, winches, spuds, power plants, and miscellaneous equipment (cranes, anchors, gyro-compass).

0948 CUSTRED, U. K. 1961 (Mar). "Hydraulic Transportation at Sydney Mine," Mining Engineering, Vol 13, No. 3, pp 279-281.

The slurry pumping system for a phosphate matrix from the Sydney Mine, Florida, is described. Total distance from mine to processing plant is about 5 miles. Draglines dump the mined matrix into a well over a bar "grizzly" to the pump intake; this is done at the risk of plugging the pipeline. Bars on the grizzly on 11-inch centers are replacing ones with 8-inch centers, and there is concomitant replacement of the 16-inch intake with an 18-inch intake. Average pumping rate is 7,600 gallons per minute at 35 percent solids (about 625 cubic yards per hour). When liquid velocity is below 11.9 fps, the line slowly plugs; beyond the minimum velocity, increased friction, pipe wear, and power consumption occur. Economy distates operation at or just above minimum velocity. Plugging is removed by pumping clear water or by shutdown and manual pipe removal/replacement. Booster pumps are spaced at 3,500-foot intervals. Two relay stations also are installed at which the matrix enters wells for processing, adding needed water, providing system equilibrium points, and for removing trapped air. The advantages of this system outweigh the disadvantages of requiring an additional person at each relay station and losing the pumping head. Pumping downhill on slopes greater than 2 percent necessitates installing "humps" in the line for air relief points and to prevent loss of pump priming; (this is because the liquid tends to flow away from the large lumps of claylike matrix when pumping downhill). Moderate uphill or vertical pumping poses no problems.

D

0949 DAVIS, D. S. 1957 (Nov). "Chart Gives Gravities of Suspensions," Chemical Engineering, Vol 64, pp 290-292.

A chart using five different nomographic scales and an additional reference axis called the beta axis is presented for use in determining the specific gravities of a solid-liquid mixture when the specific gravity of the solid and liquid are known and the percentage of solids in the mixture (by weight) is known. The nomograph is based on the equation $M = ((S/L - 1)/100)P + L$, where M is the specific gravity of the mixture, S is the specific gravity of the solid, L is the specific gravity of the liquid, and P is the percentage of solids in the mixture, by weight. One sample is given to show the three steps used in application of the chart.

0950 DAVIS, R. F. 1935 (Jul). "The Conveyance of Solid Particles by Fluid Suspension," Engineering, Vol 140, pp 1-3.

Scouring in water channels with rapid flow obviously moves both fine silt and stones considerable distances. This principle has been used by man to move sewage and mineral sludges and, more recently, in pneumatic conveyance of powders and similar materials. Velocities for initiating erosion and, conversely, settling of solids have been established and formulas have been derived. However, application of a consistent mathematical theory has not been described previously. This article presents a general principle for solids movement in both liquids and gases, and gives a practical application. Stokes Law is discussed showing that it is inappropriate for air-coal mixtures in calculating minimum airflow velocities. Turbulent flow in open pipes is described relative to its action on flaky or spherical particles, and those in between. Mathematical derivations are presented for the velocity at which particles commence to be taken up by a clear liquid flowing over them, and three formulas derived previously are discussed. The final section of the report concerns the question of whether there "is any limit to the amount of solid matter that can be carried at any given velocity," a saturation velocity. A formula is derived for this condition. The author notes, however, that with very finely divided material such as clay, in a slurry, part of the equation regarding calculation of saturation velocity may be neglected without introducing appreciable error.

0951 DE BREE, S. E. M. 1975. "Centrifugal Dredgepumps," Ports and Dredging & Oil Report, Vol 85.

Numerous graphs are presented and explained relating diesel engine running characteristics to power output and to dredge pump behavior in a direct drive situation. For the diesel engine, several ranges of operation are distinquished: the governor range, the full fuel flow range, and the range below the smoke limit (when combustion is incomplete, pollution is likely, and stalling can occur as loading fluctuates). The design and specification point of the engine, known as the

nominal full torque point, also is discussed. One graph shows how the mean working point within the full fuel flow range may be perceived when considering a known dredger, a certain type of soil, pipeline length, and attainable specific gravity. The cases of partial pipeline blockage or encountering coarser soils are dealt with, showing what types of variation result. A special section within the discussion of working in the full fuel flow range shows that fitting the pump with a smaller impeller or one with fewer blades can deal with certain circumstances which cause stalling. An advantage of few blades is that the passage is larger and the pump is less susceptible to blockage. One fundamental conclusion is that contractors generally desire tools to handle a variety of soils; with this in mind, compromising in equipment choice is often the case.

0952 DE GRACA, H. M. 1975 (Oct). "Jet Pump--A Possible Answer to Santa Cruz Port Shoaling," World Dredging and Marine Construction, Vol 11, No. 11, pp 24-26.

Sand bypassing using a jet pump "educator" may be a low cost system for permanent solution of shoaling at the Santa Cruz Harbor and other similar facilities. The harbor construction (65 nautical miles north of San Francisco) was completed in 1963, except for the sand bypassing plant. Maintenance dredging has been an annual task since 1965. Use of a 12-inch hydraulic dredge acquired in 1972 to do the bypassing was a failure because of its inability to operate in high waves at the harbor entrance. Maintenance dredging continued, being able to keep the harbor open only 8 or 9 months annually. The ideal system in this situation is one that operates in high waves, can reach all parts of a sand collection area, would not interfere with normal operations, uses a small crew, and is not prohibitively expensive. An experimental system developed at the Corps' Waterways Experiment Station answers these requirements and is built around a jet pump to pick up and discharge sand. The article describes the simple principle of operation using high velocity, low pressure pumping and a venturi nozzle, in which no moving parts are in contact with the sediment. The testing program at three different locations also is described. If this system proves effective at a practical application test at Santa Cruz, it will provide an effective means for sand transfer with a low capital investment.

0953 DE GROOT, A. J. 1964. "Mud Transport Studies in Coastal Waters from the Western Scheldt to the Danish Frontier," International Institute for Land Reclamation and Improvement, Bulletin 6, pp 5-14.

Information on the content and character of manganese compounds (fractions smaller than 16 microns) in coastal sedimentary deposits is shown to assist in determining the origins and directions of transport of mud. Although the present study considers only Holocene deposits along the North Sea coasts of Holland and Germany (using several thousand sediment analyses), other similar studies are in progress for the Amazon River of South America and Chao Phya River of Thailand. Theoretical background is given for the selection of manganese as a suitable

lso to private and public interests making damage claims; however, the nternational convention deals only with oil.

981 FEAGIN, L. B. 1946 (Nov). "Dredging Methods Compared," Civil Engineering, Vol 16, No. 11, pp 494-495.

Characteristics, advantages, and disadvantages of the "dustpan redge" and "cutterhead dredge" are compared in their general use of aintenance dredging for the Middle Mississippi River Navigation Chanel. Both types incur field costs of 5 to 8 cents per cubic yard, and oth have capacities of 1,100 to 1,800 cubic yards per hour when disharging between 10 and 14 percent solids. The dustpan dredges only oft materials, working upstream against a downstream face of a bar, and eld in place by cables anchored upstream. The path of the cut is 28 to 2 feet and, in one setting, a 3,500-foot length of shoal can be cut, ften allowing blocked boats to pass after one cutting. Spoil is disosed in shallow areas of the river; because of rapid dredge advance, horeline piping is not effectively used. A disadvantage is that time s lost in returning back to the foot of a bar for each cutting path. he cutterhead has a semispherical cutter on the suction head which llows cutting of resistant heavy materials in pieces only a few inches maller than the pipe diameter. It works downstream against a face. It an pump large quantities of loose stone and use a discharge pipe to hore of over 2,000 feet in length. It undercuts faces with little fear f the cutterhead being buried. For this reason, it is especially efective in dredging cutoff channels in the Lower Mississippi River. orking on spuds, each swath it cuts is about 250 feet long. Because it orks against a face, it must often cut through 150 to 300 feet of a bar efore a channel is available for navigation. Under especially favorble conditions, the unit cost for the dustpan is usually the lower of he two.

982 FISHER, K. 1931. "Investigation of Flow in a Centrifugal Pump," Technical Memorandum No. 1089, National Advisory Committee for Aeronautics.

This article describes a study of flow characteristics in a cenrifugal pump, primarily to explore flow processes in relation to the mpeller. Previously, assumptions necessary for the prediction of the low pattern, especially the assumption that the impeller passages alays run full with active flow, led to erroneous conceptions about the low distribution, particular for smaller flow-through amounts. This nvestigation indicated that the flow patterns in frictional fluid are undamentally different from those in frictionless liquid. In particuar, dead air space adhering to the suction side of pump impellers causes reduction of the theoretically possible delivery head. Velocity disribution also changes as a result of incomplete passage filling. Of mportance to pump design (specifically, the guide vane entrance angle), s the finding that velocity triangles at the outlet are subjected to ignificant alteration in shape as a result of increased peripheral elocity.

materials having low settling velocities, the friction factor was not affected greatly when different materials of like concentration were flowing in the pipeline, especially at higher velocities.

0979 FAIRBANK, L. C. 1941 (Oct). "Pipe-Line Flow of Solids in Suspension," Proceedings, ASCE, Vol 67, No. 8, pp 1421-1433.

The effect of suspended material upon head-capacity characteristics is important in dredging because performance is dependent on all the various units of the dredge. It is necessary to know the effect of various materials upon the individual units if an accurate prediction or estimate of performance is to be made and economic operating conditions determined. Past investigations of this type are very limited. The purpose of the investigation presented here is to obtain characteristics of a centrifugal pump of known dimensions while pumping, in suspension, materials of known sizes and concentrations. A recirculating system was used, with a 12-inch pump impeller, an inlet diameter of 5.25 inches, and materials consisting of two grades of sand and one oil-well drilling mud. Nine conclusions were formed; among the most important are: (1) at a given capacity, the head developed (in feet of mixture) by a centrifugal pump handling material in suspension is less than that developed for water alone; (2) drop in head-capacity characteristics at constant pump speed varies with concentration and with material particle size; (3) the fall velocity of suspended material is the most important property in predicting effects on pump performance; (4) the capacity at maximum efficiency of a centrifugal pump remains about constant for various sizes and concentrations of suspended materials; and (5) suspended material, of sufficient size and concentration to change pump characteristics, makes the present method of estimating pump performance from clear-water tests definitely in error.

0980 FARIS, W. M. 1973. "Liability Arising from Dredging Operations," Ocean Mining Symposium II, pp 151-165.

A realistic appraisal of liabilities stemming from pollution incidents must warrant the conclusion that dredge owners and operators face a new era with the uncertainties of the impact that these liabilities will have on their industry. The feeling of the world, generally, is that air and water pollution must be curbed. This has resulted in broad Federal legislation, international conventions, and increased civil litigation. Much of this article discusses the Federal Water Pollution Control Act of 1972 and its imposition of liability on vessel operators incurred by the U. S. Government for cleanup of oil and/or hazardous substances discharged into navigable waters. Fines, limits of liability, and legal definitions are presented for various offenses. One example of a dredge rupturing an oil pipeline in the Schuylkill River is given, in which 28,000 barrels of oil fouled vessels at a Navy base. The court held the dredge at fault as well as the pipeline and terminal companies to pick up Government expenses. An international convention, setting forth penalties similar to those of the U. S. legislation, may soon be adopted. It provides not only for repayment of costs to governments but

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0977 FADE, W. W. 1971 (Dec). "Removal of Rice Cargo from Sunken Ship with 28" Suction Dredge," Proceedings, World Dredging Conference, WODCON IV, pp 363-385.

The Panama Canal is 52 miles long, has a minimum width of 500 feet, and two-way ship traffic is a common feature. Maintenance dredging throughout the canal is a continuous problem. When a freighter carrying a load of rice and cotton struck a bank and sunk, the ship did not block the canal but presented another problem. The cargo of spoiled, fermenting rice was quickly polluting the water with high bacteria levels. Around-the-clock action was implemented to prevent intake of highly polluted water at the Miraflores Water Plant. Several methods were considered for removing the cargo: divers (as stevedores), cranes and clamshells, and suction dredging. Only suction dredging seemed appropriate for speed, cost savings, and the ability to reach rice bags in far reaches of holds. The 28-inch suction dredge MINDI was brought from another Canal location, modified with a telescoping pipe, two elbows, and a swivel. The intake end was fringed with cutting teeth to chop up the rice bags. A 7,000-foot, 28-inch pipeline was laid to a 75-acre spoil discharge area. The pumping worked, although frequent unclogging was necessary to remove tarps, timber, and rice bags. After 57 days of pumping, almost 75 percent of the rice had been removed, but more importantly, bacteria levels began decreasing after only a few days of pumping. Mud from maintenance dredging was used to cover the rice in the landfill, converting the area to a sanitary landfill.

0978 FAIKS, W. A. 1936. Transportation of Solid-Water Mixtures in Pipelines, M.S. Thesis, University of California.

This thesis research was performed to study the relationships among friction factor, velocity, concentration, and particle size of solid-water mixtures in straight, horizontal pipelines. Three fine materials were studied for specific gravity, settling velocity, particle size, and experimental determination of the effect on the friction of various concentrations. Two types of rotary drilling mud clays and crushed sand comprised the three materials studied. Settling velocity was determined to be the most important characteristic of the particles in suspended solid-water mixtures; however, this characteristic embodies many singular characteristics such as size, form, and weight of the particle, and viscosity and specific gravity of the fluid. Sections included in this report are a general discussion of theory, description of equipment, experimental procedure, results, and experimental accuracy. The most predominant feature shown was that the friction factor and the head loss of a solid-water mixture were greater than those of water and, the greater the mixture concentration, the greater the head loss and friction factor. This conflicts with other researchers who found that the friction factor and head loss were independent of concentration above the critical velocity. Experiments also showed that critical velocities were higher at higher mixtures concentrations. With fine

$0.08 to $0.30). Bucket dredges in Asia produce at $0.11 to $0.50, averaging only $0.16, per cubic yard. In addition to initial costs, rates of production, disposal means, dredging depth, material hardness, and other items are compared for hypothetical large bucket line dredges and hydraulic dredges.

0976 ERNST, R. 1967 (May). "Centrifugal Dredging Pumps," Proceedings, World Dredging Conference, WODCON I, pp 305-338.

The economy of hydraulic transport has been proven in numerous cases, in particular where large pipe diameters and delivery distances are involved. Therefore, in addition to being used for dredging for ports, channels, and other projects involving sediment movement, centrifugal pumps also have been used to move ore, coal, coral, slack, and overburden. Sometimes, two or more pumps in series are required to move material the required distance. When designing or operating a centrifugal pump, it is necessary to consider the driving unit and pipe connected to the pump. Pressure losses depend on: (1) kind and composition of solids, (2) solids concentration, (3) pipe diameter, (4) type of pipe connection, and (5) roughness of the inside of the pipe. Critical velocity, which allows no settling of the solid, is also variable. In most cases it is possible to determine with sufficient accuracy the pressure losses to be expected in systems delivering solids-water mixtures; these losses are described theoretically and by example. Hydraulic design of dredging pumps is then considered, based on statements for normal centrifugal pumps, showing that some data will have to be estimated. At this point, model-testing is introduced, along with experiments performed to date. Dredge pumps are generally made more robust than normal pumps and the construction of such pumps is discussed in the final segment of this paper. More systematic experimentation is suggested to design better pumps, and costs of repair or parts replacement should also be kept in mind during pump design.

hydraulic cutter-type pipeline dredge came into rapidly expanding use between about 1875 and 1900 when many pioneering dredging companies were formed and expanded throughout the country. The most important equipment developments that made possible the modern hydraulic dredge were the invention of the centrifugal pump (1705), the steam engine (1705), the dredge cutter (1862), and the ball joint (1900). All of these have improved greatly over the years. These machines can now move material more economically (for several miles) than can any other mode of transportation. Among the features of various sizes of hydraulic dredges covered are hulls, power sources, dredge ladders, spud gantries and spuds, dredge pumps, calves, cutters, winches and hoists, gyro compass and recording gages, pipelines, pontoons, ball joints, crews, operational bases, and operating costs. Nine photographs of dredgers, ladders, cutters, pipelines, and control rooms are presented. The trend in hydraulic dredging is to higher horsepower, lined dredge pumps, cutters with removable wear edges, and anchor handling booms. All of these features and others are cutting maintenance, downtime, and total project costs.

0974 ERICKSON, O. P. 1971 (Nov). "Comments on Hydraulic Dredges," World Dredging and Marine Construction, Vol 7, No. 12, pp 38-39.

Recent history of hydraulic dredging and its mechanical improvements in the last 25 years are briefly discussed. To be more competitive, hydraulic dredges must have stronger hulls; heavier, stronger, and more versatile ladders; and better designed cutters with strong materials and easy maintenance. Dozens of new concepts in material and design are mentioned, including several to be put into use in the near future. Among the topics covered in greater detail are use of jet pump boosters, dredge ladder design, and hydraulic dredges for mining use. Environmental considerations are becoming increasingly involved in tailings disposal.

0975 ________. 1974 (Mar). "Cost Comparisons Given for Hydraulic, Bucket Dredges," World Dredging and Marine Construction, Vol 10, No. 4, pp 21-22.

The most famous of the bucket line dredges, the Corozal, was built in 1910 at a cost of $399,344. It had two sets of buckets (34 and 54 cubic feet) and aided in construction of the Panama Canal. A memorable hydraulic dredge, the General Trembly, was built in 1954 for dredging glacial till, gravel, and boulders. In 1967 in Montreal, it placed fill for the World's Fair Exhibition, pumping boulders up to 24 inches in diameter with 15,000 horsepower and 300-rpm lined pumps. Production was 2,300 cubic yards per hour on 10,000 feet of pipeline. The Corozal could produce no more than 1,500 cubic yards per hour. Therefore, the ratio would be 1.5 in favor of the General Trembly. In addition to this comparison of two large dredging vessels, this article gives cost comparisons in consideration of a number of specific circumstances. Clamshell dredges (or orangepeel buckets) vary in production cost from $0.20 to $3.00 per cubic yard depending on material and other operating conditions. Hydraulic dredging in Florida costs $0.20 to $1.20 (average of $0.70) per cubic yard, except for phosphate rock (ranging from only

0971 ENGELHARDT, E. H. L. 1982 (May). "A Digital Approach to Dredging Efficiency," World Dredging and Marine Construction, Vol 18, No. 5, pp 7-14.

Instrumentation for dredging and offshore industries has become more and more sophisticated. Special systems are now being "tailor-made" for the cutter dredging process. This article presents details on one such digital system. The equipment makes the entire operation more perceptive to the lever man and has been proven to reduce under-dredging or overdredging, resulting in a better profile. Although pilot versions of these electrical/display systems first came into use in 1968, the "digital era" began in 1980, when analog computation was replaced by a microprocessor-controlled digital device. This instrument clearly and accurately indicates at any time the depth and width of the cutter and all information relevant to bottom and slope profiles. Much of this article is devoted to specific descriptions of the measuring instruments and the display methods. Among the major topics covered are depth and width, profile cutting, automatic spud drive control, correction for tidal level, and maintenance. The visual display is complete, including an asterisk (representing the cutter head) which follows all cutter movements on a screen.

0972 ERICKSON, O. P. 1956 (Aug). "The Hydraulic Dredge: Its History, Development, and Operation 1855-1956," Dock and Harbor Authority, pp 133-135.

A brief history of the development of hydraulic dredges shows that its inception can be traced to the invention of the centrifugal pump in 1705 and the steam engine in 1795. The first pump and steam engine on a barge that was called a hydraulic dredge became a reality in 1855 in Germany. The inventors of the first hydraulic dredge also developed the floating pontoon line with leather joint sleeves. The "General Moultrie," the first hydraulic/hopper dredge built in the United States was built in Charleston, South Carolina, in 1855. Its hull was 150 feet long and it had a 19-inch suction pipe and a 6-inch pump. It also had an "agitator" for cutting loose the hard sand. Its output was 330 cubic yards per day, but it was used quite successfully. In addition to considering further the history of the present-day cutter, most of this article contains data on present-day dredges: sizes, dredge ladder designs, spuds, pumps, engines, cutters, winches, anchor booms, suction and discharge pipes, ball joints, and shore bases. General operating, downtime, and crew rotations are covered in describing 24-hour use of a large hydraulic dredge. Operating costs vary from $15,000 per month for a 10-inch dredge, to $50,000 per month for a 20-inch dredge, and $100,000 per month for a 30-inch dredge; in rock dredging, costs would be higher.

0973 ________. 1961 (Feb). "Latest Dredging Practice," Journal, Waterways and Harbors Division, ASCE, Vol 87, No. WW1, pp 15-27.

This article gives a comprehensive overview of many mechanical and operational characteristics of the modern hydraulic dredge. The

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0969 EBERSOLE, W. C. 1971 (Apr). "Russian River Sand and Gravel Dredging," World Dredging and Marine Construction, Vol 7, No. 5, pp 21-22-24-25.

Our coastal zones are the most rapidly developing areas of the country, and they are the most delicately balanced of environments, each with its own set of landform-ocean interactions. When a gravel dredging company proposed to mine gravel for 40 years by dragline in the mouth of the Russian River north of San Francisco, and remove a 20-acre island in the process, coalitions of pro- and anti-dredging activists argued extensively. The dredging company took the stand that the area to be dredged showed an absence of fine sediments, that previous work had caused no turbidity plumes (on aerial photographs), and that stipulations added to the permit would be very stringent. The opposition contended primarily that fauna and flora downstream and in the estuary would be harmed seriously. Expert testimony on both sides resulted in a standoff, and it was apparent that baseline data were lacking upon which to base a monitoring program. Several studies were proposed, but finally, the use permit was denied. The Russian River is peaceful, but the issue is only tabled, and application for dredging may be made again. The tragedy is, we will not know anything more than we did last year, for the questions in debates will go unanswered.

0970 EHRENFELD, J. R. 1980 (Aug). "Dredging Management: Some Public Policy Perspectives," World Dredging and Marine Construction, Vol 16, No. 8, pp 19-21.

Dredging has entered a new era; only a few years ago, dredging was dredging--the mechanics, the engineering, the practice were the whole thing. Today, politics, economics, and environmental conflicts enter the picture. Spoil disposal in wetlands or almost anywhere brings about controversy. Two interesting approaches seem to have applicability to dredging problems, one is environmental mediation/planning and the other is risk management. Mediation is a voluntary, formal means to meet agreement in a deliberate fashion. It involves the skill of "third parties" to identify common positions, define facts, and foster compromise. It requires a high degree of information flow and considerable time. However, it has been successful in several cases. The primary example is the problem of dredged material disposal in Long Island Sound; mediation was assisted by the New England River Basins Commission. The basic goal of the plan ultimately reached was to accomplish dredging and disposal and still provide the highest possible level of environmental protection. Risk management is the concept that risk implies uncertainty, but that uncertainty is quantifiable through techniques such as probability analysis. Such analyses and rational evaluation of benefits and costs will help in evaluating a very subjective issue. The results of careful risk/probability analyses will perhaps result in fewer dredging projects, but would support and expedite those that are justified.

analyze and extablish the different solids (by size) settling characteristics (rate, drag coefficient) when they are being transported in a homogeneous mixture in order to achieve proper pipeline system design. This is infeasible because the apparent viscosity of a homogeneous slurry varies with the Reynolds number of flow, and therefore it is not possible to consider this supporting slurry as a perfect liquid with the same viscosity as water, but of different specific gravity. However, it is suggested that it may be possible to determine a correct settling parameter in terms of the rheological properties of a homogeneous suspension using a concentric-cylinder-type rotary viscometer. This device was used experimentally in conjunction with homogeneous clay slurries of three concentrations, and with artificial spherical particles and approximately spherical natural particles. It was confirmed that there is a relationship between the drag coefficient and the plasticity number which is similar in form to the Intermediate Law of Settling.

0968 DURAND, M. R. and CONDOLIOS, E. 1953 (May). "Concentration Measuring Instrument for Hydraulic Transportation Installations," La Houille Blanche, Vol 8, No. 2, pp 296-297.

Hydraulic transportation of solids appears to be open to great development in industry, and instruments for measuring solid-liquid mixture parameters are being developed. This article describes a new instrument for measuring solids concentrations, which is applicable both in the laboratory and in industrial practice (where the use of direct outlet sampling or delicate electronic gauges is unsuitable). The principle relies on two pressure tappings on a section of vertical pipe. Pressures are transmitted to a differential manometer by connecting tubes filled with clear water. Improvements to the initial design are explained to eliminate the "head loss in clear water" leaving only the "head loss in the mixture." These two terms differ only by the weight of solids present; therefore, the concentration measurement is reduced to the reading given by an ordinary differential manometer.

with material. Seven examples are briefly discussed, including the 108-mile-long Ohio coal clurry line, the 72-mile-long gilsonite line from Utah to Colorado, several cement mixture lines, a china clay line, and a pneumatic colliery line used to "stow" waste dirt in deplected coal seams. American pipe standards are compared to those being developed in Great Britain. Materials for solids pipelines are not much different from the steels used in high pressure oil or gas pipelines. However, protection systems must sometimes be improved. This may involve abrasion wear resistance by addition of hardened plates along the pipe bottom or by applying certain epoxy resins, rubber, plastics, or ceramic linings. External protection needs are no different than arising in other pipelines. Experimental work is briefly covered, as are the topics of flow characteristics for slurries with coarse particles (one-eighth inch or larger) and fine particles (less than one-eighth inch diameter).

0966 DUNN, J. T. 1968 (Oct). "Use of Digital Computers in Dredge Design," Proceedings, World Dredging Conference, WODCON II, pp 650-676.

Modern dredges are becoming increasingly complex and expensive, as are the projects they are assisting with. A dredge should receive the same level of engineering skill as other complex systems (such as ships, airplanes, and automobiles). A powerful tool for this is the digital computer, but it must be properly used or can be a burden or economic drain. Three areas are presented in which the computer can assist, all in the category of design engineering: (1) use for repetitive calculations, (2) general analyses so difficult that they are seldom done manually, and (3) mathematical simulation modeling. Among the topics covered with a thorough but simplified approach are weight/trim calculations, structural analyses (using internal and external loadings and shear forces), and a mathematical model of a slurry pump system, (including suction mouth, suction tube, and discharge line with various joints and elbows). It is pointed out that all these aids to engineering are now in practice and are making jobs easier and designs better. The use of the computer has six advantages: (1) data are easy to prepare, (2) engineering time is saved, (3) rapid design results are obtainable, (4) analyses can be repeated for many conditions, (5) results are more realistic than those obtained by other methods, and (6) results are well organized and documented for future reference.

0967 DU PLESSIS, M. P. and ANSLEY, R. W. 1967 (Jul). "Settling Parameters in Solids Pipelining," Journal, Pipeline Division, ASCE, pp 1-17.

Pumping of solid-liquid mixtures in pipelines has been developing for over 60 years, and it has been demonstrated that the introduction of a suspension of fine solids (clay) beneficially affects transport of coarse solid fractions. Suspensions of fine solids are considered to behave as homogeneous fluids, exhibiting non-Newtonian flow characteristics (typically, Bingham plastic characteristics). It is necessary to

was the first of these constructed in 1972-1973 in 3 m of water. Winter slope protection consisted of synthetic fiber cloth overlain with chain-link fencing and submarine netting. Because of the necessity of some islands to last as long as 25 years, various types of protection systems are being considered; materials testing is an ongoing process as islands are being constructed in deeper water. Because of the huge amounts of fill material required for the underwater slope as depth increases, more islands are being constructed with a sandbag retained area. This is especially true if available fill materials are finer sands and silts rather than coarse sand or gravel. The land-fast ice zone extends to the 30-m water depth. Beyond this, multiple ridges form in the shear zone. Unfortunately, the most significant hydrocarbon deposits are in the shear zone, and design and construction of protection systems for semipermanent islands is a massive task. Several examples of methods being considered are discussed. Specialized dredging vessels and other equipment are described.

0964 DRAHOS, F. R. 1958 (Mar). "Right Material Cuts Pump Corrosion," Chemical Engineering, Vol 65, pp 162-166.

Corrosion is a major problem in most chemical plants, but proper economic choice of materials in constructing pumps are lowering material losses, maintenance, and downtime costs. Six common types of corrosion are described, ranging from galvanic corrosion (which occurs when two dissimilar metals are in contact in an electrolyte) to cavitation erosion (formation and sudden collapse of gas bubbles which particularly affects suction side of impeller blades). Other types are uniform corrosion, erosion corrosion, intergranular erosion, and pitting. Material economics shows that large surfaces like tanks, vats, and pipelines often can be most economically protected by coatings or linings. Centrifugal pumps, however, with small, irregular, intricate surface areas coming in contact with corrosive fluids, justifiably require the use of more expensive corrosion-resisting materials. Materials specified should be reasonable for the job at hand. If chemicals being processed are very valuable and can be contaminated by corrosion, use of high-cost materials is justified. Among the pump materials further described, along with their corrosion resistance, are: cast iron, cast steel, wrought steel, carbon steel, brass, bronze, chrome iron and steel (seven times more expensive than carbon steel), chrome-nickel stainless steel, and more highly alloyed nickel-based materials. The most economical may truly be those that provide the longest, trouble-free service.

0965 DRAKE, R. and THURSTON, H. G. 1964 (Oct). "Pipes for the Conveyance of Solids," International Pipes and Pipelines, Vol 9, No. 10, pp 39-44.

A general overview of existing pipelines used for solids conveyance is presented; included are hydraulic and pneumatic systems. Additional data on flow characteristics and abrasion are given. Because it is known that 70 to 80 percent of the total cost of a pipeline project is for the pipe installed in the ground, new developments should concentrate on pipe material and installation. This paper primarily deals

This survey concerns itself mainly with the problems presented by pipeline transportation of coal-water mixtures. It assumes that coal will have been processed to remove abrasive impurities and crushed to the required size. Among the industry opinions collected are that coal can be transported economically by pipeline if adequate design and full-scale performance data can be gathered, that commercial development of pipelines undoubtedly would be accompanied by specifically designed pumps for such service, and that percentage of coal (by weight) that could be pumped ranges from 25 to 40 percent. Very few performance data or literature sources exist relating to the subject. Conditions listed as affecting pumping performance include size and shape of largest particles, size of pipeline, linear velocity, screen analysis, weight of solids per volume, specific gravity, erosion of pipe and pumps, degradation characteristics of the coal, and pressure drop in the line. The article concludes with a number of economic study comparisons and several tables concerning data gathered during the survey. An addendum concerns the 12-inch, 17,000-foot, full-scale demonstration pipeline to be built by Pittsburgh Consolidation Coal Company near Cadiz, Ohio.

0962 DOWNHAM, R. 1971 (Jul). "Dredging and Dredgers," Consulting Engineer, pp 45-49.

Dredging techniques and the dredging vessels are both rapidly changing. A careful study of factors involved in dredging and selection of equipment is as important to the engineer as creation of a new port or expansion of existing facilities. Both capital and maintenance dredging projects should be carefully costed; costs will depend on nature of material, distance to suitable spoil disposal area, and value put on reclaimed land, among other things. One of the most important factors in port site selection is cost of maintenance dredging. Contract documents drawn for dredging work should define areas, depth, and materials by use of borings. Hydrographic and meteorological aspects of the project area should be realistically assessed. Mobilization costs and payment method should be worked out, and positioning ability should be looked at when selecting dredgers. Much of the work of a consulting engineer in dredging is selecting or designing the dredging plant, which must handle maximum desired depth, and the worst sea and wind conditions expected. Four types of dredgers (and auxiliary equipment, such as hopper barges and tugs), are discussed relative to their capabilities and limitations. The four types are trailing-suction hopper dredgers, cutter suction dredgers, bucket dredgers, and grab dredgers. Combinations of these are sometimes useful. Recent developments in studying materials and improving equipment conclude the discussion.

0963 DOWNIE, K. A. and COULTER, D. E. 1980 (Oct). "Shore Protection for Hydrocarbon Production Islands Located in Artic Regions," Proceedings, World Dredging Conference, WODCON IX, pp 553-570.

Since 1972, a number of temporary and semipermanent islands have been constructed of local bottom materials in Canadian and Alaskan waters of the Artic Beaufort Sea for hydrocarbon exploration. Immerk B48

testing of new, large equipment. But the time has come for improvement and applying dredging techniques to mining for at least two reasons: (1) the grade of accessible mineral deposits is decreasing and capacity and efficiency must increase; and (2) mining offshore at greater depths and in rougher seas requires new approaches to equipment. Several examples are given of how dredging vessel and pipeline improvements can be applied to alluvial mining. Ruggedness, flexibility, and improved instrumentation are some of the features discussed for the equipment.

0959 DONKIN, C. T. B. 1959. Elementary Practical Hydraulics of Flow in Pipes, Oxford University Press, London.

Elementary principles and basic formulas associated with hydraulic flow in pipes are covered in this book intended for use by engineers and draftsmen. Most of the content is devoted to the flow of water, but many other problems also are confronted. Numerous graphic and tabular support data illustrate topics covered in the text, and most data are expressed both in English and metric units. Readers are assumed to be thoroughly familar with common machinery and apparatus referenced. Twelve chapters comprise the main text; eighteen appendices present units of measurement, coefficient derivations, and various types of data. The following subjects are reviewed: water at rest and in motion; the concepts of quantity, velocity, and diameter; viscosity and Reynolds number; flow through orifices, over weirs, and pipes; exponential and logarithmic flow formulas; and friction in bends and changes of section. A separate chapter encompasses piping problem examples. The chemistry of water and fluids used in pipeline systems is not covered, but layout schemes for water supplies receive substantial emphasis. The economics and alternatives of design fundamentals are given attention.

0960 DOORMAN, G. 1958. "Dredging," pp 629-642.

Many ports and rivers have been kept free of sediments for centuries. This article describes some of the very earliest dredging equipment in seven categories: (1) removal of silt in suspension; (2) scoops; (3) ladle-dredgers; (4) grab-dredgers; (5) wheel-dredgers; (6) chain- or bucket-dredgers; and (7) accessories (such as mud hoppers and spikes to break hard material). Removal of silt in shallow conditions was often done by narrowing a river with crib-dams or by transverse raking. A ship called a "mole" that was wind driven, had a broad stern widened by hinged leeboards, and with iron-toothed rakes on the bottom, was in use as early as 1435. In a patent of 1589, the use of "tubes" for conveying mud, clay, sand, or other material for land deposit was mentioned; it was incapable of realization. Specific ships and dredging projects, as well as detailed operating characteristics are given. Virtually all early dredging (fourteenth to nineteenth century) was in Europe.

0961 DOUGHERTY, R. W. 1951. "A Survey on the Hydraulic Transportation of Coal," Report of Investigations No. 4799, U. S. Department of the Interior, Bureau of Mines.

material may remain in spaces between the valves; sand or silt is easily flushed out.

0956 DE KONING, J. 1971. "Field Observations of Density Flow to the Suction of a Suction Dredger in Sand Pits," The North Sea Spectrum, Norspec 70, pp 231-238.

During dredging operations, soil is "liquified" by one or more of several types of flow that maintain slurry pumping: hydraulic erosion, hydraulic tractive force (the slurry is driven by the surrounding water), or density flow (flow originates from static potential of the soil). Underdigging occurs as an unwanted additional phenomenon, causing spillage of spoil when mechanical means of disintegration (bucket dredger, cutter suction dredger) are in use. Several diagrams are used in conjunction with explanations to indicate observed actions of sand sediments as affected during dredging. Specific examples in deep borrow pits are presented. Introduction of the submerged sandpump changes the flow pattern of "slurry rivers" in sand pits.

0957 DENNING, R. A. 1965 (Feb). "Calibrating Nuclear Gages for Slurry Density," Control Engineering, Vol 12, No. 2, pp 79-81.

Gamma ray density meters do not measure density directly, but they measure an amount of radiation reaching a detector after having passed through the material being measured. The material absorbs and scatters the gamma rays, thus decreasing radiation intensity from its source value. Attenuation of gamma rays by an absorbing material follows an exponential curve. To obtain accurate readings, the installation and initial calibration of such a meter require special attention. This article describes factors affecting slurry density measurements, shows how to calculate a readout scale, and provides useful formulas for determining radiation source requirements for construction of a gamma ray density meter. Calibration intervals and installation precautions also are described. Because solids are not distributed evenly within a pipe, in slurry flows, horizontal measurements through the pipe should be avoided. Locating the radiation beam along a vertical diameter provides a more accurate measurement because a more complete distribution of particle sizes within the pipe is sampled. Locations downstream of elbows also should be avoided, as should areas containing cavitation bubbles.

0958 DONKERS, J. M. 1970 (Jul). "Some Aspects of Modern Alluvial Mining," Proceedings, World Dredging Conference, WODCON III.

The dredging industry can be of valuable assistance to the modern alluvial mining industry in providing answers to some long-term problems that have persisted and often made alluvial mining less efficient than it had to be. Dredge development has been marked in physical size, output capacity, and technical refinement, but dredging equipment for alluvial mining has not shown similar development. Five reasons are given for this condition. One of the major reasons is that funding has simply not been supplied on the part of the mining industries for full-scale

indicator element. Selection of samples then is discussed, followed by a detailed analysis of the results, which relate manganese content (extrapolated to 100 percent of the fraction less than 16 microns) to origin and movement at the number of coastal areas. Several maps help clarify the discussion.

0954 DE GROOT, R. 1971. "Dredging Pipelines and Pumps," Ports and Dredging, Vol 69, pp 4-9.

The object of this article is to show that, by application of criteria related to the pipeline and pump and precise analysis of a number of variables, optimum use of a dredger can be made, or a production problem often can be solved by a relatively small adjustment of the pump or pipeline. Seven charts are discussed in detail which describe characteristics of pipelines and pumps operated under different conditions of soil type, pipeline length, pipeline diameter, and impeller number or size. It is shown how five components of total resitance are related. To have precise information for any job, the soil should be analyzed. Working ranges are described for both small- and large-diameter pipelines. Similarly, restrictions to pump working ranges are shown graphically. These analyses point out that using larger discharge lines can increase pumped quantities, but the working range will be narrower unless suction line bore also is increased. In order to choose the right impeller, characteristics of the pump/pipeline set in question must be known. A simple equation is provided to improve pump r.p.m. when one is incapable of running at full r.p.m. on a given job. Where dredging quantity is not limited by the amount loosened by a cutter or other factors, to obtain maximum production it is recommended that "the minimum quantity be pumped at the highest concentration possible with the available pump head." For a given power, the quantity of sand obtainable through a pipeline is greatest at its critical velocity.

0955 ________. 1971. "IHC Sliding Bottom Valves," Ports and Dredging, Vol 72, pp 4-8.

Dredge builders have searched for years to find a method to discharge spoil from hopper vessels in shallow water without striking bottom. Several systems have been devised, but the IHC system using two rows of sliding valves (2 × 2 m) has proven to be an excellent technique. Several varieties of hopper barges and dredges may be fitted with these valves, but they are best used on the largest trailing-suction hopper dredges. Several diagrams and photographs accompany a verbal description of the method of operation. Among the features pointed out are that the apertures are suitably large because no internal mechanisms interfere, a watertight seal exists when pumping out is dictated, the system is easy to dismantle (but is reliable and robust), and the system adds to a lower center of gravity because of the lack of deck-mounted actuating devices. Testing of the system is described. Two disadvantages are: (1) incorporation of the system gives a less smooth bottom line, thereby decreasing vessel speeds by 0.1 to 0.2 knots, and (2) where clay or large rock is loaded, several cubic meters of

0983 FLORJANCIC, D. 1970. "Influence of Gas and Air Admission on the Behavior of Single- and Multi-Stage Pumps," Sulzer Research, No. 1970, pp 35-44.

Air and gas (argon) injection effects were studied on single- and multi-stage pump characteristics. Three means of causing such effects occur during practical operation: entrainment of air from a sump, poor sealing of a pump inlet line, and intentional application (or unavoidable presence) in chemical processes or to control cavitation noise. A standard, three-stage, segment-type pump was converted and run with either one or three stages under air and argon injection. Inlet pressure, gas delivery rate, and number of stages were varied under constant speed. An additional test determined the influence of air content on the axial thrust of multi-stage pumps. Numerous graphs show test results. With test data generated, it is now known that the susceptibility of pump characteristics to parameters such as inlet pressure, head coefficient of impeller inlet, number of stages, and gas constant can be estimated for a pump with a specific speed of about 100. Estimation of reduction of axial thrust in multi-stage pumps also is possible. No valid relation between drop in head and air injection volume could be found, even for the optimum point flow rate. It appears that the air core at the impeller inlet has a major influence on the flow, and therefore on the pressure increase.

0984 FORESTER, R. H. ET AL. 1969 (Jan). "Effects of Polymer Addition on Friction in a 10-Inch Diameter Pipe," Journal, Hydronautics Engineering Notes, Vol 3, No. 1, pp 59-62.

Previous testing has shown that friction reductions of up to 80 percent in turbulent liquid flows can be achieved by the addition of small amounts of certain soluble, linear, high molecular weight polymers (weights of one to several million). These earlier studies used only small diameter pipes (less than 2-inch diameter). The present study uses a 10-inch pipe and a polymer designed to add to slurries for rapid dispersal and pumping, hence making storage bulk of the slurries considerably reduced. A concentrated slurry polymer was injected in the centerline of the 10-inch horizontal pipe 95 feet ahead of an 88-foot test section. Pressure drop could be measured over the length of test section. Results are plotted for the velocity ranges of 1.5 to 15 feet per second (Fanning friction factor plotted against Reynolds number based on water properties). Friction reductions were evident, although it appeared that incomplete polymer mixing took place in only 95 feet. After the polymer was present and for most flow conditions, the flow would increase 20 to 30 percent throughout the 88-foot pipe length, over that obtained using raw water. A reduction in pressure drop of over 40 percent occurred in the last 42 feet of the measuring section at velocities between 5 and 15 feet per second. Indications are that pressure loss reductions as great as 50 percent may occur in longer pipes. These results may have utility in water handling systems that are subject to occasional overloading, such as storm sewers.

0985 FORNESI, R. 1959 (Nov). "Mechanical Seals for Slurry Service," Industrial and Engineering Chemistry, Vol 51, No. 11, pp 59A-60A.

Amorphous-type solids usually found with organic chemicals are often not abrasive, and can be sealed with a single seal. However, such a slurry has a tendency to gum up seal springs, sometimes resulting in failure. A solution to this problem is using an outside seal, so that the pumped material is not in contact with the springs. Any recommendation for use of a single seal on an abrasive slurry should consider viscosity, pressure, surface tension, and particle size. If previous experience is not available, it is suggested that the following seal types be used (recommended in order of preference): (1) single seal with clear liquid injection, (2) double seals, (3) quench gland. The quench gland is especially suitable when pumping liquids or slurries and abrasive conditions are caused by atmospheric contact. For example, a saturated salt solution may cool and cause crystallization of salts at the seal faces. By circulating a quench liquid around the seal faces, any salts formed will be dissolved in and flushed away by the quench liquid. Quench liquid should not be turned off, even though the pump is not operating, because vaporization or crystallization may continue.

0986 FORTINO, E. B. 1959 (May). "Viscosity and Pumpability Study of Bottom Material in a Dredging Channel," Report No. 1, U. S. Army Engineer District, Philadelphia, CE, Philadelphia, Pa.

Dredge pumps usually are designed with the pumping of sand-water mixtures in mind; however, they also are frequently used to pump muds, silts, and clays, especially during channel maintenance. Consideration is given at the pump design stage of pumping viscous mud directly. Prior work is scarce, confined to the pumping of viscous oils, but it clearly indicates that when viscosity increases, a general depression of the curves of head and efficiency plotted against pump capacity occurs (when compared to the same pumps pumping water). The experiments reported validate the concept that mud can be regarded as a viscous material, and they were designed to determine the viscous properties. The sample materials first were accurately and thoroughly defined using rheological studies. Samples consisted of Delaware River and Hudson River muds; both have properties of a Bingham plastic. Calculations show that tested material is not pumpable in its natural state by current hopper dredge pumping systems. It is pumpable in its natural state (density of 1,401 g/l) if the dredge pump were located at the draghead. The material also would be pumpable if diluted to 1,200 g/l.

0987 FRITTS, S. S. 1961 (Jul). "Practical Considerations in Pumping Slurry," Pit and Quarry, Vol 54, No. 1, pp 155-156.

This article is particularly aimed at pipeline and pump considerations when dealing with cement mill slurries. Various equations are given for general determination of theoretical pumping volume, friction factor, head loss, and pipeline diameter. Power requirements calculations also are shown. One table presents fundamental characteristics of water-solids mixtures, with the gallons per minute required to move

1,000 barrels of equivalent dry solids per hour. Pulp density is based on specific gravity of solids being pumped, averaging 2.70 for dry material. A second table gives recommended pipe sizes based on an equation derived in the text which accounts for friction, moisture content, specific gravity, and other parameters.

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0988 GARDE, R. J. 1956 (Oct). Sediment Transport Through Pipes, M.S. Thesis, Colorado Agricultural and Mechanical College, Fort Collins, Colo.

Sediment transport can either involve alluvial channels (formed of the same material as that being transported) or be contained in rigid boundaries (open or closed pipes). This paper deals only with the sediment transport phenomena through pipes, with special reference to: (1) effect of boundary form, such as smooth, helical corrugated, or standard corrugated; (2) effect of sediment characteristics, such as mean diameter and particle size distribution; and (3) effect of nature of transport (fully suspended, partly suspended and partly carried along the bottom). Experimental data were obtained only from 12-inch-diameter pipes of each form, only one size of sediment (mean diameter = 0.60 mm), and only full pipe flow conditions using water as the liquid phase. Thesis sections include a literature review, theoretical consideration, descriptions of equipment and procedures, and presentation of data. A total of ten summarized findings are presented along with five conclusions. Among the conclusions are: (1) considering the aspect of energy requirement for transporting a given quantity of sediment (of a given size), helical corrugated pipe is the most economical; (2) the resistance coefficient f is adequate to study the flow of water-sediment mixture through all three boundary forms, and (3) f is affected by the sediment concentration and the characteristics of sediment and boundary form.

0989 GAUSS, G. A. "Acoustic Techniques for Geological Studies with Particular Reference to Dredging Problems," Presented by Hunting Geology & Geophysics Ltd, pp 147-153.

Acoustic techniques provide a rapid and relatively inexpensive means of gaining information on bottom and subbottom conditions of the Continental Shelf. All of the techniques have limitations, and it is highly suggested that, in areas with little geological documentation, borehole data should be used as a supplement to acoustic data. Several types of acoustic equipment are described: side-scanning sonar, acoustic profilers, continuous profiling systems. The use of such equipment has come about because of the recent improvement in position-fixing systems with errors of only a few meters per 100 km. The continuous profiling system is very useful in determining dredging requirements for harbor maintenance or for locating new harbor sites. The extent and depth of "buried channels" can be evaluated using profiling systems. Normal presentation of acoustic survey results would include: (1) a contour map showing depth of rock head either beneath the seabed or beneath a specified tide datum; (2) representative interpreted seismic profiles across the channel at regular intervals (and other instructive profiles); and (3) a full survey report with discussions of diagrammed results. Seabed contour maps also are often produced.

0990 GAY, E. C., NELSON, P. A., and ARMSTRONG, W. P. 1969 (Nov). "Flow Properties of Suspensions with High Solids Concentration," Journal, AICE, Vol 15, No. 6, pp 815-822.

Laminar flow behavior was investigated for several suspensions containing high percentages of solids (28 to 55 percent by volume). Suspensions studied included liquid sodium-nickel, xylene-nickel, xylene-alumina, glycerin-alumina, glycerin-nickel, glycerin-copper, and glycerin-glass spheres. Theoretical viscosity equations were derived, and values of many physical properties were used to correlate the theoretical equations with measurements of suspension viscosities. A technique was developed for calculating suspension flow rates as a function of pressure drop. Measurements were made in uniquely designed pipeline viscometers which minimized end effects by having pressure taps that could measure pressure gradients without disturbing the flow and that were located 26 inches from the ends of the viscometer. Correlation equations generated herein fit all systems studied. It was found that high-solids suspensions exhibit a yield stress which is directly proportional to the diameter of the particles and inversely proportional to the volume of free liquid. Size distribution and shape of particles also affect yield stress, however, liquid properties, except as they affect the maximum solids fraction, have no apparent effect. Three regions of flow can be identified for high-solids suspensions; low, intermediate, and high shear rate regions.

0991 GEMINDER, R. and LECOURT, E. J., JR. 1972 (Jul). "Deep Ocean Mining System Tested," World Dredging and Marine Construction, Vol 8, No. 8, pp 35-38.

In 1970, a prototype test took place for deep ocean mining of manganese nodule deposits (in 2,500 feet of water off the Georgia-Florida Coast). This test used a noneconomical deposit; the ultimate goal is to mine in the Pacific Ocean at 18,000-foot depths where economic deposits exist. The range of instruments, methods of sensor placement, and means of recording data during the test are described. The mining system used a surface ship, dredge pipe (9 and 5/8 inches), dredge head (which raked the ocean floor), nodule separator, weighing conveyor, and storage bin. One of the most important mechanisms was the air-lift pump system which injected compressed air into the dredge pipe from one-third to two-thirds the depth being dredged. This caused air, water, and nodules to flow up to the ship. Air was experimentally injected at three different depths by using remotely controlled values. An underwater television system was installed on the dredge head. Measured parameters were: axial/bending/torsional strains in the dredge pipe, angle of the pipe (to vertical), roll/pitch/heave of the ship, pipe pressure, pipe flow, airflow, and nodule delivery.

0992 GERSTEIN, L. and BOYER, E. 1978 (May). "Hydraulic Haulage System of the Hansa Hydro Mine -- Planning and Design, Construction, Operation," Proceedings, Hydrotransport 5, BHRA, Paper J7, pp 87-99.

After 2-1/2 years of planning, design, and construction, the first section of the Hansa Hydro Mine began operation in the last quarter of 1977. The coal mine was converted from one of conventional to hydraulic mining because of the remaining steeply inclined seams. This paper describes in moderate detail the various system components, new research and testing being carried out, and backup and maintenance methods. The entire system is designed to produce 3,500 tons per day of coal crushed to less than 60-mm diameter. Coal is hydromechanically removed from seams and transported in flumes to two centralized feeding stations (with extra holding capacity in case of system shutdown). The two feeding stations use several single-stage centrifugal pumps in series to pump the slurry (at a 6-1 water-to-coal ratio) to the feeding station for the vertical haulage. The two feeding stations must pump 2,200 and 2,900 m, respectively. Vertical pumping of 850 m at a target production of 5,000 tons of coal per day was necessary. All new installations had to be carried out while conventional mining continued. A three-chamber pipe feeder system made it possible to pump large volumes of coarse material at high pressure without the necessity of passing the material through the high-pressure pumps. The entire plant system is run from a central control station.

0993 GLAS, J. 1975 (Jun). "Method Proposed for Decreasing Fuel Consumption," World Dredging and Marine Construction, Vol 11, No. 7, p 16.

The land-based shovel and floating dipper dredges are best suited for removal of hard material because of highest cutting force per area of cutting edge and relatively low power usage. The cutter suction dredge has high force on cutting edges, but it uses considerably more power to rotate the cutter and operate the winch. Depending on the cutter's diameter, the suction intake is sometimes 1 meter from the bottom, and this means that not all loosened soil can be taken in. For marine mining of tin and gold, where the ore is found just above the hard bottom, cutter suction dredges do not pick up much of the ore. Consequently, bucket dredges are used primarily in mining. A new concept combines the positive effects of the bucket type and suction dredge. A bucket with cutting teeth is mounted on a cutter dredge ladder. Variable speed winches, capable of operating at from 0 to 15 meters per minute, are used in conjunction with vertical pulling cables. The dredgemaster can work vertically, horizontally, or on a slope upward from left to right, as desired. Spuds or bow and aft cables can be used for maneuvering. For tin mining, the entire bucket chain can be omitted. The ore mixture would be pumped directly through the screen to the jig. For normal sand dredging, the cutter and cutter drive can be forgotten.

0994 GLIDDON, B. J. 1957. "The Hydraulic Transport of Solids in Vertical Pipe-Lines," Journal, Chemical Engineering Society, Vol 11, pp 152-161.

This article discusses theoretical considerations of hydraulic transport of solids in vertical pipes, and describes a new test apparatus for determining pressure drop during vertical conveyance. In horizontal conveyance, flow characteristics may be quite complex; however, in vertical transport the problem is much simpler and conveying always will take place if the water velocity exceeds particle settling velocity. In practice, the settling rate of a particle is influenced by other particles around it. When solids are introduced into a fluid stream, the pressure drop depends on particle diameter, shape, concentration, and density. For any given pipe and particle size, the pressure drop will be a function of the solid concentration and velocity; therefore, any experimental system must be designed so that these two variables can be measured accurately. The design described has a 1.003-inch-diameter brass test section 42 feet high. It has four pressure tappings at 10-foot intervals. A rubber-lined pump is used, and velocity in the test line is controlled by a diaphragm valve in the bypass line. The pump can handle solids up to 3/16-inch diameter and solid concentrations to 70 percent by weight. Experiments and previous work described herein may be particularly applicable for designing economical ways of raising coal to the surface. The output of a large colliery could be pumped to the surface through a 1-foot-diameter pipe which would cost relatively little to install.

0995 GONGWER, C. A. 1940 (Jun). "A Theory of Cavitation Flow in Centrifugal-Pipe Impellers," Transactions, American Society of Mechanical Engineers, Vol 63, pp 29-40.

The development of cavitation in hydraulic pumps and turbines has long been recognized as a detriment that limits operating ranges, causes destructive pitting (erosion), and reduces machinery efficiency. This article presents an overview of existing methods used to describe pump cavitation performance from the standpoint of the influence of impeller eye design characteristics. From experimental data, it is shown that cavitation performance is influenced by the "angle of attack" of the vane leading edges. Coefficients are derived for pressure drop due to vanes and shrouds separately. The concept of "suction specific speed" is defined, related to three impeller eye parameters, and interpreted with respect to design implications. "Cavitation plots" show that the discontinuity in the pump-discharge characteristic curves is caused by a "stall" (or separation of flow) in the eye. Basic assumptions early in this work include: (1) the impeller eye is characterized by the lowest absolute pressures and, hence, is the region where critical cavitation conditions are likely, and (2) the impeller eye diameter typifies (for defining peripheral velocities) the diameter of the imaginary surface of revolution described by the leading edges of the impeller vanes. These assumptions are justified for the analysis presented.

0996 GOODIER, L. J. 1967 (Oct). "Dredging Systems for Deep Ocean Mining," Proceedings, World Dredging Conference, WODCON I, pp 669-696.

This article considers many aspects of the use of dredging equipment for ocean mining, and there is considerable mineral potential on both the Continental Shelf and the deep ocean floor. Dredgers have, in effect, moved huge quantities of minerals from place to place each year but have never exploited them. Dredgers, engineers, technological firms, and governments have all been slow to develop marine mineral production except in a few specific cases. Great Britain recovers 7.7 percent of annual coal production from underseas, while that of the Japanese is 20 percent. Because of limited space, the Japanese also store minerals in shallow sea areas. Data are presented on current sea mineral mining and anticipated reserves. Specific mineral mining techniques and economics are discussed for phosphate, manganese nodules, diamonds, and tin. Hydraulic dredging, bucket dredging, and airlift dredging are described in relation to their most appropriate mining uses. Deep ocean mining at 12,000 feet is discussed for manganese nodules, but technology has not yet been developed to handle the immense amount of equipment needed. One of the most severe problems to be encountered in deep sea mining is maintaining production under very unstable and rough sea conditions; modified flat-bottom barges in tandem may help solve the problem. The biggest concern to offshore dredgers is to protect the ladder rather than barge. Installed cost may be $50 to $60 per shaft horsepower now, but gas turbine authorities claim this may be reduced to $10.

0997 GOODIER, L. J. 1981 (Dec). "Marconaflo Systems for use as Self-Contained Dredging Units," World Dredging and Marine Construction, Vol 17, No. 12, pp 30-31.

Marconaflo slurry pumping systems have been in use about 12 years to hydraulically transport solids within plant locations, but they can be used in several dredging applications: (1) unloading sand and mud scows onto disposal sites, (2) distributing dredged materials within diked disposal sites to maintain standard height, and (3) portable dredging on inland lakes or at remote locations. The portable units can be fixed to platforms or suspended. The principle of operation is one in which the unit sinks itself into a high density slurry (or dry material) using water forced through high pressure "sinking jets." Once at a chosen depth, the Marconajet(s) is activated, and the horizontal moving jet stream undercuts cavity sidewalls. Material flows toward the self-contained slurry pump and is piped to a desired location. The effective radius of the cavity depends on natural "launder slope" of the material, sluff angle, degree of compaction, and volume and velocity of the jet stream; it can range from 50 to 175 feet. The unit can be sunk deeper (by the jets) or moved. On a skid or barge, the unit can be moved continuously. Six systems are available, ranging in size from the DJ04 (7 feet high, 6,000 pounds, requiring 150 to 350 gallons per minute water and 20 to 40 horsepower) to the DJ14 (22 feet high, 28,000 pounds, requiring 2,000 to 4,000 gallons per minute water and 250 to 500 horsepower). The percent solids (by weight) of pumped slurries ranges from 35 to 65 percent. The largest unit can move 300 to 900 tons of slurry per hour.

0998 GORDON, G. and GORDON, M. K. 1973 (Dec). "Island Created for Runway," World Dredging and Marine Construction, Vol 9, No. 14, pp 54-56.

Dredgers of Universal Dredging Corporation are creating an island immediately offshore, to the south of Hawaii's International Airport, for eventual construction of a new 12,000-foot runway. The 36-inch cutter suction dredger Hydro-Pacific is moving most of the 20 million cubic yards of hard coral from nearby areas to the fill site via pipeline. Areas as deep as 28 feet will have to be filled, and the maximum elevation will be 20 feet above sea level. After considerable legal battles over concerns for environmental problems, the injunction against dredging was lifted on October 10, 1973. The $5 million Hydro-Pacific delivers 50,000 cubic yards per day to fill the 775-acre area. It is dredging at depths of from 15 to 60 feet, and has lost several teeth on the cutterhead and suffered occasional pump jamming. During a recent overhaul, 26,000 pounds of hard face welding rod were used to renew the pump volute. The pump is powered by a General Electric 10,000 rated horsepower motor, providing up to 16,000 actual horsepower for turning the main pump that handles 60,000 gallons per minute. A 3,000-horsepower motor turns the cutter head. A power cable barge, carrying 15,000 feet of cable, connects the dredger's breaker panel with an onshore transformer where 14,000 volts is on tap. Work is continuing 7 days a week and, because of legal delays, many of the shore crew are having to learn pipe moving and other chores quickly under difficult conditions.

0999 GOSLINE, J. E. and O'BRIEN, M. P. 1934. "The Water Jet Pump," University of California Publications in Engineering, Vol 3, No. 3, pp 167-190.

The Hydraulic Laboratory at the University of California is carrying out a series of studies on pump designs and operational theories; this article concerns the water jet pump. The objective is to provide a satisfactory theory where one is lacking and to check theory by experimentation. The basic principle of the jet pump is the transfer of momentum from one stream of fluid to another, and the jet pump possesses the advantages of involving neither compressibility or heat transfer. The relatively low efficiency of the jet pump has limited its applications to those where absence of valves and working parts and/or small size are sufficient advantages to offset greater power requirements. After presenting general theory (especially concerning the applicability of the momentum equation), efficiency, cavitation, energy loss, and other aspects are discussed. Two different jet pumps are described from which experimental data were obtained, one a small, cylindrical commercial pump, and a constructed "sectional pump." A total of 786 runs were made on pumps having area ratios from 12.4 to 96 percent, with a maximum nozzle pressure of 85 pounds per square inch. The most important result is the verification of theoretical equations (shown in text) and their statement in dimensionless form. Agreement between theory and practice in the water jet pump is "notably good," but possibilities for improvement are evident, particularly with regard to design of the nozzle,

mixing chamber, and diffuser angle. With certain design changes, a maximum efficiency of 40 percent may be possible.

1000 GOVIER, G. W. and CHARLES, M. E. 1961 (Aug). "The Hydraulics of the Pipeline Flow of Solid-Liquid Mixtures," Engineering Journal, Vol 44, No. 8, pp 50-57.

In recent years, pipeline flow studies of multiphase mixtures have increased because of the need to move minerals over relatively great distances. Canadian studies include coal-water, coal-oil, sulphur-gasoline, and sulphur-condensate mixtures. The solids are transported either as "settling" or "nonsettling" mixtures. Nonsettling mixtures can be defined as those for which solids settling velocity is less than 0.002 to 0.005 feet per second, whereas they often behave as non-Newtonian fluids and, in a high concentration (30 to 40 percent by volume), generally behave as Bingham plastics. Settling mixtures cannot be treated as "single-phase" systems except in high turbulence. The behavior of settling and nonsettling mixtures is markedly different in hydraulic transport. For settling mixtures, the rate of settling depends on particle size, shape, and density; concentration of particles; liquid density, viscosity, and velocity; and the pipeline geometry. For spherical particles, drag coefficients can be evaluated from certain equations, but for nonspherical particles, drag coefficient must generally be determined experimentally. In low concentrations, sand particles less than 20 to 35 microns, sulphur less than 30 to 50 microns, and coal less than 35 to 60 microns are considered nonsettling. In the case of nonsettling slurry, the settling effect may be neglected and the mixture treated as a homogeneous fluid. In a settling slurry, the settling effect cannot be neglected except at extremely high velocity. Durand and Newitt equations are able to adequately predict pressure gradients and transition velocities for settling slurries.

1001 GRAF, W. H. 1967. "A Modified Venturimeter for Measuring Two-Phase Flow or, Particle Dynamics and the Venturimeter," Journal, Hydraulic Research, IAHR, Vol 5, No. 3, pp 161-187.

A specially modified Venturi meter is described and tested as a measuring device for solid-liquid mixtures, specifically for sand-water combinations. Besides measuring the usually recorded pressure drop, the design also permitted measuring pressure loss across the meter. It is shown by theory and experimental data that the pressure readings in terms of mixture give information on the flow rate. The energy loss was correlated with particle concentration; an attempt also was made to explain this by theory. An equation to explain slow motion of a spherical particle under the influence of gravity in a moving liquid was modified to represent more rapid movement (at higher Reynolds number). Because the concept of "virtual mass" seems to be important for a completely valid derivation, and existing literature on this topic is incomplete, the explanation offered probably is of limited value. A modified Venturi meter as suggested will provide an opportunity to determine continuously the flow rate of a mixture and its concentration. However, a trial-and-error approach or a nomogram will lead to reliable determinations of these parameters.

1002 GREEN, J. L. 1961 (May). "Pneumatic Breakwaters to Protect Dredges," Journal, Waterways and Harbors Division, ASCE, Vol 87, No. WW2, pp 67-87.

The use of pneumatic breakwaters is a possible solution to reducing impacts on near-shore or port dredging operations. Pneumatic breakwaters consist of a submerged perforated pipe through which compressed air is forced; the pipe may be suspended or rest on the ocean floor. As the compressed air rises from the performations and forms a curtain of bubbles, it creates an upward and outward motion of the air-water mixture, opposing the incoming waves. The L/d ratio (length of wave divided by depth of water) is the most important indicator of conditions in which such breakwaters are effective. Pneumatic breakwaters are most effective against "deep-water waves" (when L/d = 2 or less). This article traces the history, development, and testing of pneumatic breakwaters in many locations and conditions from 1925 to 1961. Model tests and theory are presented, along with several tables of airflow and power requirements to stop waves of certain lengths (periods). A detailed description is given of tests off the New Jersey coast, including use of portable, multiple, parallel breakwaters. A new British design uses intermittent pulses or large air volumes; this appears to be a more effective system because the large bursts of air create vortices which interrupt the orbital motion of a wave at greater depth and cause it to partially destroy itself. Reasonable protection would be an effective reduction of 40 percent in wave heights. The maximum attenuation that can be obtained with unlimited air supply decreases as the L/d ratio increases.

1003 GREGORY, W. B. 1927 (Mar). "Pumping Clay Slurry Through a Four-Inch Pipe," Mechanical Engineering, ASME, Vol 49, No. 6, pp 609-616.

This study evolved from a need by a cement company in New Orleans for raw materials. One possible excellent source was fine clay solids from the city's water treatment plant (60,000 tons annually). Because the solids had to be pumped about 8.6 miles, a 4-inch pipeline test system was devised. The experimental layout for the test system is described, and theoretical evaluations of parameters related to system design are discussed. The test pipe included two 100-foot straight sections and a "U" with two elbows. The pump ran at 1,750 rpm and was rated at 300 gallons per minute at 45 feet head. Suction on the pump was 4 inches, but discharge was 3 inches. Mercury differential gages were tapped into the system at several points to measure losses. The results from the pumping experiments with various percentages of solids (by weight) of the settling pond clays are, as far as the author is aware, the first of their kind ever generated. Solids content by weight varied from 18.6 to 35.3 percent, with turbid water pumped first as a baseline test. The major conclusions are: (1) the clay material can be pumped as a slurry with only simple engineering involved; (2) the most economical velocity for pumping is at the critical velocity; and (3) the apparent viscosity of the slurry at the critical velocity varied from 24

to 85 times that of water, depending on amount of solids present. It also was noted that the clay slurry was not truly viscous as is oil.

1004 GUICHET, B. 1979 (Jul). "Underwater Pump Increases Capability and Performance of Williams-McWilliams Dredge 'Diesel'," World Dredging and Marine Construction, Vol 15, No. 7, p 16.

The 30-inch-discharge, cutterhead dredge "Diesel" was fitted with new underwater pumps to make it one of the most efficient dredges in the United States. Waterproof pumps mounted on the ladder can give a 25 to 50 percent increase in production. This new technology was developed to permit deeper suction dredging for such projects as deep-water pipeline crossings. The pump chosen for the "Diesel" is driven by two 450 horsepower electric motors sealed in watertight containers. The ship was redesigned with a hull extension of 32 feet, an elevated lever-room for better operator vision, and a new ladder of 67 feet with three 30-foot extensions. The new pump system can be mounted on any one of the ladder extensions or be completely removed when not needed. The new ladder weighs 176 tons, and a stress analysis of the ship's hull was necessary prior to mounting the ladder. In addition to requiring the hull extension and ladder support system, a new ladder hoist was needed. The first job upon completion involved movement of 2 million cubic yards of material for expansion of the New Orleans Lakefront Airport; this required dredging to 85 feet. The job continued at 35 percent better efficiency than before ship modification. Total modification costs were about $1 million.

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1005 HADJIDAKIS, A. 1968. "Increasing the Output of Trailing Dredgers when Working in Compacted Fine Sand," Ports and Dredging, Vol 60, pp 4-8.

In recent years, many trailing-suction hopper-dredging operations have required removal of compacted fine sand. This material not only overflows hoppers substantially, but causes diminished intake at the drag head. Experiments are described which incorporate new designs in drag heads to loosen compacted fine sand, but also which minimize wear on equipment and use little additional towing force. Experiments using vibrating knives and rotating disc-type cutters were abandoned quickly because of severe wear problems. However, it was found that vertical water jets mounted in front of suction inlets could provide a suitable answer, provided that correct positioning of jet nozzles was used. The experiments discussed were carried out on both Dutch-type and Californian drag heads with variable numbers and sizes of vertical or shielded water jets. The best results in terms of production, trailing power requirements, and jet force were obtained with the Dutch head fitted with six small shielded jets. In terms of production alone, the Dutch head with six large shielded jets was better, but only at the expense of greater trailing power. For a given production, energy requirements for a vertical jet system was found to be 70 percent of the energy absorbed by the dredge pump; a shielded jet system required only 35 percent of the dredge pump power.

1006 __________. 1970 (Oct). "Deep Water Dredgers of the Future -- Five Designs," Hydrospace, pp 24-27.

Several types of dredger have been built which can work in water depths of over 100 feet, including tin mining bucket dredgers, grab dredgers, and suction-type sand/gravel dredgers. The common feature of all these, however, is that they are only capable of working in calm-water areas. Several new feasible designs have been evaluated which can carry out specific dredging functions in deep water and under rough conditions. Five such designs are pictured and described in this article. One is a deep water trailing suction dredger with a U-shaped frame supporting a long ladder with submerged dredge pumps. Such a vessel can operate efficiently in high waves because of special swell compensators and a flexible coupling in the ladder. It can dredge to 200 feet below the water surface. A second type is a cutter dredger; four configurations of these are described. Each type has at least one or more major components submerged, working on the ocean bottom directly. But they also extend to the surface, having operating columns, part of the frame, a support hull, or some other feature either protruding from or floating on the surface. Designs shown are for deltic work, deep trenching, deep cutting, and caisson preparation. All types are portable by flotation.

07 HADJIDAKIS, A. 1970. "Optimum Utilization of Cutter Dredgers," Ports and Dredging, Vol 65, pp 4-8.

This article provides insights into factors which determine the oduction obtainable from a cutter dredger. These factors basically e related to cutter and swing power requirements, vacuum requirements, owrate commensurate with avoidance of sedimentation in the delivery ne, and pump drive power. The initial premise is that the output of a tter dredger is governed by the quantity of material dislodged per it of time. This in turn is controlled by numerous soil characteris- cs, cutter design, depth and direction of cuts, and vessel movement. all, thirteen independent parameters are listed, but these cannot be mbined simply into a formula showing interrelationships. The major pics discussed are limits of vacuum, limits of pumping power, and mits of critical velocity. Where the output of a cutter is determined the vacuum, the attainable maximum output decreases as the suction pth increases. Jet pumps are a suggested means of boosting output at eater suction depths. Length of pipeline, type of soil, and power to ive the pumps are among other critical factors to attaining maximum tput. Three representative examples are given in which improvement of tput can be realized by various means. Basic knowledge of the soil to dredged would be most helpful in increasing production.

08 HAMATA, F. 1975 (Jun). "Dredge Pumps Operated in Parallel on Lake Winnipeg Channel Project," World Dredging and Marine Construction, Vol 11, No. 7, pp 34-37.

In order to meet severe time constraints in dredging two channels the northeast end of Lake Winnipeg, Canada, Sceptre Dredging and Dilngham of Canada built a dual-pump system for a 36-inch dredge. A 36-ch pump could not be ordered in time to gain an extra 5 months of ice-ee dredging, so two 24-inch pumps were connected by a "Y" and elbows. e entire dredge--200 feet long, 50 feet wide, and 8 feet deep--was ilt for the job from sectional pontoons. Three 5,000 horsepower nchronous motors turned DC generators which powered the pump motors, tter, and hoisting gear. Once assembled, the craft was towed to the edging site, but not quite in time. The dredge was "iced in" on the ke in early November (only one day's travel from its destination), and could not be freed until the following June. Meanwhile, laboratory del tests helped assess the probable effectiveness of the parallel mp system. Even after beginning actual dredging, extremely hard rock evented full in-the-field assessment, but the following conclusions uld be made: (1) the two pumps were not difficult to balance during erations and their response to loading changes was smooth; (2) there s an inability to reach full rpm on the pumps due to DC motor torque aracteristics; and (3) the pumps cavitated at relatively low digging cuum. Model tests had failed to indicate this latter problem.

09 HANOCQ, C. 1928. "Experimental Study of Loss of Head in a Closed Pipe Carrying Clay Slurry," Translated from Revue Universelle des Mines, Vol 17, No. 3, pp 75-78.

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ITAYA, T. and NISHIKAWA, T. 1964 (Aug). "Study on Sand Pump, First Report, on the Trajectories of Solid Particles in the Pump Impeller," Bulletin, Japanese Society of Mechanical Engineers, Vol 7, No. 7, pp 577-582.

This article describes the flow of spherical glass beads (mean :ters ranging from 5.19 mm to 12.57 mm) through the impeller of a :e pump with water. The trajectories of the beads were recorded ›graphically with a high speed camera to determine the relative ve- :ies and directions at the impeller exit. A method for numerically ılating the trajectories (motions of particles) also is shown. The :ically calculated results coincide fairly well with the experimen- r observed courses, but only when the inlet conditions are known. of the particles had little effect on the velocity and direction of ›articles at the impeller exit, and relative velocity changed little a change of outlet angle of the impeller (between 15 and 35 de- ;). Scatter in experimental data was ascribed to the nonuniform in the impeller.

IWANAMI, S. and TACHIBANA, M. 1969 (Apr). "Flow Properties of Stable Slurries, First Report, Experiment," Bulletin, Japanese Society of Mechanical Engineers, Vol 12, No. 50, pp 224-230.

Experiments are described related to flow properties of suspen- s and slurries through three types of viscometers. Materials used : (1) spherical particles of methyl-methacrylate (MMA); (2) non- rical particles of polyethylene (PE); and (3) nonspherical particles olyvinyl chloride (PVC). Suspending liquids were mostly aqueous erin solutions, but "diluted water glass" was used also for the yl-methacrylate particles. Mean diameters of the particles ranged 58.2 microns to 254 microns for MMA, and were 97.4 microns and microns for PE and PVC, respectively. The three viscometers in- ed a rotational type, a short tube type, and a capillary type. Cor- ion for end efforts were used on the rotational viscometer. Infor- on presented is on the rate of shear and shearing stress or apparent osity as particle concentration varied between 0 and 45 percent, different particle sizes. It was concluded that flow properties not independent of the type of viscometer used; the apparent vis- ty determined by the capillary viscometer is lower than that shown rotational viscometer, at the same shear rate. MMA slurry is shown e a Newtonian fluid in the concentration range from 0 to 20 percent, PE and PVC slurries become non-Newtonian fluids at lower concentra- s (about 10 percent). Oliver's constant for MMA slurry of 2.60 es with experimental data.

edging for laymen, students, engineers, and executives. The English stem of weights and measures is used. The initial chapter deals with e history of dredging, and introduces operations of modern dredges. bsequent chapters are devoted to ramifications of modern dredges. Subquent chapters are devoted to ramifications of operation of the hydrauc pipeline cutterhead dredge. Empirical data as well as theoretical inciples are presented. Not only are all components of the hydraulic edge described, but aspects such as obtaining permits, mobilization, rveying, job layout, volume calculation, contracting, cost management, d personnel selection also are covered. Several chapters are devoted major pieces of equipment such as the pump and the prime mover, and the hydraulics of the entire system. Appendices give information on rious types of contracts.

34 HUSTON, J. 1980 (Jul). "Dredging's New Language," World Dredging and Marine Construction, Vol 16, No. 7, pp 25-28.

Conversations among dredgemen today include terminology not used ıst a few years ago. The new "parlance" has been brought on by the environmentalists, the EPA, and the general conversion to the metric sys:m. In this article, several commonly used terms are defined, and exıples are given to clarify their meaning to the dredge operators. It noted also that dredged material is no longer called "spoil." Much the explanation deals with measuring dredge output, comparing volume r apparent volume) measurements with the newly accepted weight measure ıeaning dry weight of the dredge material). Formulas are given for calılating density in grams per liter (percent concentration of dredge ıterial in the solid-liquid mixture). Other terms described include ımbient" and "background" concentration, "percentage removal effi.ency," "K factor," and "finer than 100." The K factor is a term for ıterial density classification. The term "finer than 100" refers to a ıterial whose grains are fine enough to pass through a sieve with 100 ıenings per linear inch of sieve screen.

)31 HUBBARD, M. 1975 (May). "Dredging Operations Abound in 'Flat Water' State of Nebraska," World Dredging and Marine Construction, Vol 11, No. 6, pp 45-46.

It has been estimated that dredging operations account for 50 per- ent of the nation's sand and gravel production. In Nebraska, more than) percent of dredging operations recover sand and gravel, primarily rom man-made pits, at depths from 20 to 100 feet. The state supports re dredging operations than any of the other 49 states, with from 125 › 200 dredges operating annually depending on local economic conditions id construction funding. The sand and gravel is used mostly for port- ind cement, asphaltic concrete, and gravel road surfacing. Most pump izes used are 8-inch or 10-inch, with a few smaller or up to 16-inch iameter. Dredging from the man-made lakes in valleys is advantageous ecause of shallow water tables in many areas. Sophisticated equipment is come into more prominent use recently, and booster pumps are being sed to help recover sand at greater depths. Nebraska can expect to re- iin in an advantageous position with its vast supplies of sand and ravel.

)32 HUSTON, J. 1967 (Aug). "Dredging Fundamentals," Journal, Waterways and Harbors Division, ASCE, Vol 93, No. WW3, pp 45-69.

Literature on dredging is almost nil, and the dredging industry, mpared with similar-sized industries, is near the bottom of the list 1 time, effort, and money devoted to study, research, and development. redging is complicated, but data gathered on it are mostly empirical; iere is no real apprenticeship, only experience. This article adds to ie little available literature, and is concerned with a broad spectrum f dredging operations from its history to how production is measured. iny of the major functional components of a typical dredge are ex- lained, but only the hydraulic cutterhead dredge with pipeline disposal stem is considered in detail because it is the "world's most versatile cavator since invention of the shovel." Early history of dredging is vered from the time of the "mudmills" to the inventions of the steam igine, cutter, spuds, ladder, and pipeline. Among the dredge compo- ents described briefly are the cutter, ladder, suction, hull, hoists, ever room, pump, spuds, and discharge lines. A typical dredging opera- ion is described from arrival of the equipment through the first swing f the cut. Production parameters and measurements are outlined. Top- cs that need further investigation include measurements and recording f velocity, quantity, and percentage of solids; the application of ieology; and pipeline friction values.

)33 __________. 1970. Hydraulic Dredging Theoretical and Applied, Cornell Maritime Press, Inc., Cambridge, Md.

Up until recently, dredging has been little publicized or pub- ished. With the organization in the last few years of the World Dredg- ig Association (WODA) and the World Dredging Conference (WODCON), much seful information is emerging, especially from the European countries. 1 this book is presently useful and practical information on hydraulic

Maintaining tidal river waterways in a navigable state is the topic of this article. Maintenance entails all types of activities required to ensure safety for shipping traffic, including: performing routine depth soundings; measuring hydrologic parameters (flow patterns); assessing early damage to groynes or jetties; maintaining signals, buoys, and other navigation security systems; and performing maintenance dredging. The specific task of maintenance dredging is enlarged upon by considering general methodologies and limitations such as funding, lack of suitable disposal areas, improper equipment, and meeting environmental requirements. The discussions are based primarily on experiences in the Federal Republic of Germany on three major rivers, the Elbe, Weser, and Ems. A number of examples are presented on causes of recurring silt or soil deposits in navigation channels in a variety of circumstances. Approaches to limiting and removing such deposits, and the effects of currents on morphological changes, are explained. It is noted that, where fresh and salt water meet, maximum siltation occurs when and where the salt content is about 0.5 percent. The most important considerations in maintenance dredging are related to hydrographic variables (width and depth of channel, distance between dredging and disposal sites, current force and direction, and the kind, dimensions, and composition of deposits to be removed.) Emphasis throughout the discussion is placed on the utility of trailing-suction hopper dredges for tidal river dredging.

1030 HOWARD, G. W. 1938 (Sep). "Transportation of Sand and Gravel in a Four-Inch Pipe," Proceedings, ASCE, Vol 64, pp 1377-1391.

This study presents findings of tests on 4-inch pipe carrying varying concentrations of sand and "pea gravel" at velocities from 6.0 to 13.0 feet per second. Although few previous similar studies have been done, data from two studies are included. The test apparatus is a system which maintained a constant solid concentration as velocity varied, resulting in a uniform circulation of mixtures, constant pressure, and even distribution of solids over the cross-sectional areas of the pipe. Transparent pipe allowed visual observations. The "economical velocity" of sand transport is defined as the velocity at which any given volume per hour can be moved through a known pipe length with the least expenditure of power per unit of sand transported. Among the eight general conclusions are the following: (1) Sand and gravel moves in pipes in three ways, rolling along the bottom at slow velocities, "jerking" along at medium velocities, and moving steadily (all particles) at higher velocities; (2) the largest quantity of sand is transported in the lower third of a pipe rather than against the bottom; (3) for sand, the friction factor (f) decreases with an increase in velocity, and increases with an increase in solids concentration at any velocity; (4) economical velocity for solids transport depends on the character of material, and each class of material will have a different economical velocity for the same pipe size; and (5) transfer of results from a small pipeline to one of greater diameter can only be qualitative and is not governed by any law of corresponding velocities.

demands that tend to increase costs. This appears insurmountable, but one solution has appeared on the market to help answer the question "Where am I?" The solution is electronic positioning equipment manufactured by a number of companies. These positioning devices can continuously indicate the position of dredges and survey boats relative to shoals, channel lines, buoy markers, and structural landmarks. The systems are particularly valuable in reducing lost time caused by foggy, rainy, or hazy weather conditions; this results in a definite cost savings of perhaps as much as $300 per hour for rental of large vessels. The systems generally measure the distance (electronically) to two transponders on the shore by the use of microwave energy pulses from a ship-mounted transmitter. Using the distances and that between the transponders, the vessel's position is determined by trilateration. Most of the systems can be ordered with peripheral equipment such as automatic data loggers and x-y flatbed plotters (which give a permanent record on a nautical chart for later use). Such things as track indicators and track repeaters also can be purchased. Benefits other than use in poor visibility include better performance within desired dimensions for dredging, showing exact starting and stopping points, locating open-sea disposal areas, and permitting determination of hopper loads by knowing exact length and speed over a cut.

1028 HOPMAN, R. J. 1973 (Sep). "Doppler Speed Log Praised," World Dredging and Marine Construction, Vol 9, No. 11, pp 32-34.

Electronic positioning equipment is a must in the dredging industry for numerous reasons. In the Pacific Northwest alone, over 700 hours of operating time of dredges and survey boats are lost annually because of limited visibility. Electronic positioning eliminates downtime due to reliance on visual observations, or to reliance on lasers which also depend on visibility. Although more than 10 electronic navigation and positioning systems presently are on the market, the one discussed is the doppler sonar system, which measures velocity and distance traveled. This particular system requires no shore-based equipment. The operating principle involves a four-piece electric crystal array which generates four doppler sonar beams (in the fore, aft, port, and starboard directions). Each crystal is both a transmitter and receiver working in pulsed timing. Information received on the return signals is processed by a built-in, hand-wired digital processor to compute vessel velocity and distance traveled, as well as direction. The speed log gives immediate, direct-reading indication of ground speed so a mate can judge forward or athwart ship (port and starboard) speed to prevent "setting back" on dragpipes or for proper positioning when dredging next to a dock, jetty, or submerged bank or structure (pipeline, etc.) of known location. Speeds are indicated by the doppler system in 0.01 foot per second. Numerous effective uses of such electronic positioning systems are described for dredging applications.

1029 HOVERS, G. 1973. "Maintenance Dredging in Tidal Rivers," Terra et Aqua, Vol 3, No. 4, pp 36-41.

diamonds. The "harvesting" method used for all three types of deposit is a dredge. For most alluvial deposits, particularly for tin, dredging methods are by conventional bucket dredges or simple suction dredges. Some offshore mining operations have required development of specialized dredging systems. The examples discussed here are ones that have recently been applied to the exploitation of alluvial diamond deposits in water up to 200 meters deep. Historically, this offshore diamond mining used dredges to remove sandy overburden, and divers to manually retrieve diamond-bearing gravel in cracks and on the bedrock. Two diamonds the size of match heads in one cubic meter of gravel represent a payable deposit. Among the specialized equipment tested for improving efficiency at greater depths are the air-lift system (effective to 170 meters) and the water jet pump concept. Other advances include using high resolution scanning sonar, acoustic television, and low light television. The systems described have been successful. For shallow water, these systems may have numerous applications in surf zones, bays, and rivers.

1026 HOLL, J. W. 1960. "The Effect of Air Content on the Occurrence of Cavitation," Journal, Basic Engineering, ASME, Vol 82D, No. 4, pp 941-946.

There has been very little information generated regarding the occurrence of cavitation on two-dimensional bodies, although there has been extensive work on three-dimensional bodies. A series of tests on two designs of two-dimensional hydrofoils are reported on here. Precise definitions of incipient cavitation (first appearance when pressure is lowered) and desinent cavitation (point of disappearance of bubbles as pressure is raised) are given. Past experiments show that desinent pressure is greater than or equal to incipient pressure resulting in "cavitation hysteresis." The chord lengths of the hydrofoils tested were from 2 to 5 inches, and tests used "angles of attack" from 0 to 3 degrees at water velocities of 30 to 70 feet per second. Water temperature was 75 degrees, and dissolved air content ranged from 6 to 17 parts per million. Test curves showing desinent cavitation number versus stream velocity are presented, along with a discussion of two types of desinent cavitation. Major conclusions are that: (1) the difference between the desinent cavitation number for gaseous and for vaporous cavitation is directly proportional to the dissolved air content and inversely proportional to the square of the velocity; (2) gaseous cavitation can occur at very high ambient pressures; (3) to minimize effects of air content, tests should be run at low air contents and high velocities; and (4) high-speed photographic studies should be made of the bubble growth process.

1027 HOPMAN, R. J. 1972 (Sep). "A Means of Determining a Dredge's Whereabouts," World Dredging and Marine Construction, Vol 8, No. 10, pp 14-16.

Pressure is increasing on the nation's dredging fleet to dredge deeper, faster, and cheaper, and still meet all of the environmental

In addition to building the most modern and longest pier conveyor loading facility in the country, the company changed procedures from one of using hydraulic pumping from a small pit fed by bulldozer or front-end loader to one of using a small dredge with suction pump on a platform that floats in shallow ponds (3 to 4 feet deep). The mini-dredge allowed recovery of more ore, a slightly higher grade concentrate, lower grade of discharged tailings (as percent iron oxide), and lower heavy equipment use. The bottom of the ore deposit is only 10 feet below water level. The system involves two units: a dredge unit for ore excavation/suction and slurry delivery; and a four-drum magnetic separator for beneficiation. The dredge is installed on twin pontoons for mobility. Sand is loosened and slurried (15 to 30 percent solids) by water jets, and sucked up by a 6/4 pump driven by a 225-horsepower diesel engine. The slurry is delivered to the magnetic separator through polyethylene pipes. Tailings are stockpiled for recycling or used as backfill.

1024 HILL, J. C. C. 1962 (Jul). "Pumping Solids by Jet Venturi," Mine and Quarry Engineering, Vol 28, pp 304-311.

The jetpump system offers advantages in several applications of hydraulic transport of solids. By using only a jetpump, the pumps supplying the driving water handle only clean liquid; therefore, wear and replacement involves only a simple mixing chamber section in the pipe system. A jetpump system known as the Acrow Jetlift is described, along with several applications. Its performance characteristics are similar to those of a centrifugal pump system except that, with increasing depth, the head required to overcome the difference in specific gravity between the slurry inside the pipe and outside remains constant. The characteristics of a jetpump system that may be adjusted to give maximum efficiency for a given task are nozzle or throat diameter, pressure, and quantity. Because jetpumps do not handle the solids directly, they are capable of handling relatively larger diameter pieces (6-inch particle diameters in an 8-inch unit). When installed on the suction side of centrifugal pumps, the jetpump can result in increasing solids concentration (production) by 50 to 100 percent, particularly in fine materials and with an agitator jet at the intake to the suction pipe. Several ideal applications of the Jetlift system are found in the offshore mining industry, and the system is excellently suited to combine with a dredger-mounted primary treatment plant. Additional advantages of the jetpump arrangement include: suction power does not decrease with wear, maintenance is inexpensive and simple, and there is a constant load on the prime mover regardless of surging or the concentration of solids being pumped.

1025 __________. 1980 (May). "Specialized Dredge Systems for Alluvial Minerals," World Dredging and Marine Construction, Vol 14, No. 5, pp 15-16.

Offshore mineral deposits generally fall within three categories: deep ocean nodule deposits, low-value sand and gravel deposits in shallow water, and high-value alluvial minerals such as gold, tin, and

for a vessel to be able to recover offshore sand deposits are ability to operate in open seas, mobility and low drag during transit, capability to dredge to 100 feet or more, and high-efficiency, low-cost operations (preferably with a capability of 2,000 cubic yards per hour or more). The cutterhead dredges meet some requirements, but cannot operate in high waves of over 2 to 3 feet because of shock loading to ladders, trunnions, and hulls. Operability in seas with a wave height of 6.6 feet would establish a 95 percent on-the-job record along Continental U. S. coasts. Semi-submersibles can meet the requirements even though transit is limited. Structural design of a catamaran can "dampen" wave action considerably, provide a stable working platform, and give cost-efficient results. Partially submerged pontoon hulls with transverse structural numbers can also be used effectively.

1022 HERUM, F. L., ISAACS, G. W., and PEART, R. M. 1966. "Flow Properties of Highly Viscus Organic Pastes and Slurries," Transactions, ASCE, Vol 9, No. 1, pp 45-51.

Wide interest has developed lately in pneumatic and hydraulic transport, particularly for inorganic substances such as sand, coal, salt brine, and ores. Developments are much more recent with organic slurries. The study reported herein concerns a special rheometer developed to measure flow characteristics of highly viscous organic fluids (ground corn paste, swine ration, and ground meat, all mixed in water). Typical Newtonian fluid flow and non-Newtonian flow are described. Non-Newtonian flows, depending on behavior of shear stress, can be of several types. Also, the flow properties of some non-Newtonian fluids can be time dependent. For example, corn paste and swine ration absorb water with time and shear stresses increase with holding time. The opposite effect is observed in ground meat paste. An "extrusion rheometer," using pistons to force test fluids back and forth through test sections, was designed and built. This apparatus is briefly described. The rheometer gave satisfactory results for identifying and quantifying the major flow parameters of the organic fluids tested. All three substances could be described as "power law fluids." The totally enclosed rheometer, using strain gages as pressure transducers, is an effective device for determining shear diagrams of highly viscous organic fluids. However, time and temperature effects cannot be completely separated, but these uncontrolled effects are small. Different fluids exhibit diverse effects, and special testing programs may be required to obtain complete shear diagrms for each fluid of interest.

1023 HIDALGO, I. O. 1972 (Mar). "Mini-Dredge (Iron Sand Mining) in the Phillipines," World Dredging and Marine Construction, Vol 8, No. 4, pp 13-15.

FILMAG, Inc., is a wholly-owned Filipino corporation that pioneered iron sand mining in the Phillipines, with commercial production since 1964. The company owns 94 placer claims along a 150-mile coastal stretch of Luzon Island. Production requirements increased from 100,000 tons per year in 1965 to 400,000 tons in 1969 and 720,000 tons in 1970.

discharge lines at present. Systematic studies are needed for head losses with various solid-water mixtures (also for nodules for deep ocean mining). Efficiency of booster pumps and jet-assist pumping needs further study. The final section of this article describes the new Center for Dredging Studies being established at Texas A&M University, College Station, Texas. The facility will occupy part of a 6,440-square-foot Hydromechanics Laboratory. Test facilities there will include a large dredge pump test loop, a cutterhead towing tank, a four-pump dredging system loop, and a small pump water and erosion test stand. It is hoped that the dredging industry will be able and willing to support the Center.

1020 HERBICH, J. B. 1969 (Dec). "Methods for Deep-Ocean Mineral Recovery," Proceedings, Civil Engineering in the Oceans II, ASCE, pp 297-313.

Mining of mineral deposits from the ocean beach deposits, continental shelves, and deep-sea floor will require some form of dredging for economical exploitation. Land reserves of many minerals may be almost exhausted by the year 2000, and companies are looking at techniques for future marine dredging. Although a great number of methods have been suggested, this article examines the most promising method of hydraulic suction dredging. Among the basic designs put forth are "walking platforms" with jet-assisted pumps working on the ocean floor, crawler tractor types with snorkel to surface, "flip ships" which move under their own power and then flip vertically for dredging, and submarine "ore lifters" which load on the ocean bottom and then ascend for unloading. Using the hydraulic suction technique, discussion is subdivided into three categories: (1) pump located on a ship or floating platform, (2) pumping assisted by jet pumps (air or water lifts), and (3) pump located at the bottom. Several design criteria and examples are given for these categories. It is pointed out that numerous man-induced or natural hazards may affect success of deep-ocean dredging. Several bold new ventures are described. One large offshore mining rig could produce the following percentages of U. S. production: manganese (25%), nickel (10%), copper (1%), and cobalt (40%). Improvements are needed in working in heavier seas nearshore up to 400 feet deep), then, as methods are perfected work to intermediate depth (400-1,200 feet), and eventually to 15,000 feet.

1021 HERBICH, J. B. and LOU, Y. K. 1975 (Sep). "Catamarans for Offshore Dredging," Work Boat, Vol 32, No. 9, pp 58-59.

Because beach erosion is a serious worldwide problem, encompassing nearly 2,700 miles of beaches in the United States alone, suitable means for restoring and managing beaches are being studied. Some techniques include hauling or dredge pumping sand in for replenishment. But nearshore estuarine, or inland sand is becoming harder to get economically. The use of catamaran or semisubmersible dredges capable of deep dredging can help, although much more study and construction experience is needed to reduce fabrication problems. The four main requirements

relationship of discharge angle to position of particle. Absolute and radial velocity conditions were studied in relation to impeller action. The major conclusion is that design discharge at the design speed gives the most uniform distribution of velocity across the vane opening. Slower pump speeds caused slightly higher particle discharge angles than progressively faster speeds; high speeds caused adhesion of particles to vane surfaces. A particle behavior analysis such as that performed here can reveal more about internal pump composition than can any external measuring device.

1018 HERBICH, J. B. 1968 (Aug). "Dredging Fundamentals," Journal, Waterways and Harbors Division, ASCE, Vol 94, No. WW3, pp 362-370.

Results of specific research on seven topics related to dredge pump performance are summarized. The topics include: improving pump efficiency by changing design, using multiple pumps to increase output, solid particle motion within a dredge pump, effect of solid-liquid mixture viscosity on cavitation, impeller modifications to improve cavitation behavior, study of gas removal systems, and a suction dredging literature survey. With respect to making changes in dredge pump design to improve efficiency, several shapes of vanes and exit vane angles were studied leading to recommendations for five modifications. The ultimate conclusion was that the efficiency of a dredge pump may be increased (8 to 12 percent), depending on the liquid density, through impeller redesign. Studies on using multiple pumps showed that such a combined system has advantages over two pumps discharging through separate lines and incurring added head loss. Solid particle motion studies discovered that the average recirculation of spherical beads was 26 percent, and this varied little with pump speed or discharge. With respect to studies on impellers and cavitation, it was found that heavier liquid mixtures caused cavitation to occur at a lower specific speed. Improved gas removal systems need to be developed. Characteristic curves for pump operation are urged to be adopted in dimensionless form for efficiency without having to use multiple plots for each pump speed, impeller diameter, or specific gravity.

1019 ________. 1969 (Mar). "Dredging Industry Problems that Need Solving," Ocean Industry, pp 59-63.

Previously, there has been little coordinated research and development initiated by the various dredging companies; most effort has come from individuals, universities, and allied equipment industries. Further research needs can be categorized into the following five groups: (1) dredging machinery (pumps, dragheads, cutterheads), (2) discharge pipe systems (wyes, elbows, reducers, ball joints, floating lines), (3) special machinery (jet pumps, gas removal systems, booster pumps, multiple-pump dredge systems), (4) quantity measurements (viscosity, velocity, discharge, density), and (5) flow of slurries (optimum velocities, resistance, rheology). Recommended studies are outlined for many of the factors mentioned. Mechanical efficiency and cavitation of pumps need special attention. No additional information is needed on floating

draft). Each year about 170 miles are dredged. During a normal dredging year, about 61.3 million cubic yards are dredged; this equals 25 percent of the Corps' entire nationwide maintenance dredging. Dredging in the Mississippi River alone accounts for 20.7 million cubic yards, while other maintained areas normally require 2 to 13.5 million cubic yards to be removed. During "flood years," when proportionately more silt comes into the lower area of Louisiana, amounts of dredging can more than triple. Average cost to maintain the Mississippi River from Baton Rouge to the Gulf of Mexico (42-foot-depth contour) usually is about $3.2 million; after a "flood year" costs have jumped to $13.7 million. East of the Mississippi River, a 36-foot-deep, 76-mile-long alternate route to the Gulf is being developed (CENTROPORT U.S.A.); it is connected to the river by a lock system and requires considerably less maintenance dredging than do many channels. Ongoing dredging varies in frequency from annually to once every 10 or more years in some areas.

1016 HENDERSON, J. M. 1966 (Jan). "A Mass Flowmeter for Granular Material," Transactions, ISA, Vol 5, No. 1, pp 78-83.

The mass flow rate of granular materials can be measured by an instrument described in this article. Two formulas, an initial one and one modified to account for "step flow rate distribution," are derived. Among other things, the modified theory is based on the assumption that the relationship of radial velocity to position is linear. The principles of fluid flowmeter operations apply well to granular material, but because conveying granular material (in air) to, through, and from these fluid meters is severely limited, a new versatile design is given based on the change of angular momentum. Test data are graphically represented for several features of meter performance. Three materials were used in experimental testing of the meter--sand, kiln-dried spruce sawdust, and shelled field corn. Tests showed that recalibrating the meter was not necessary to account for material differences.

1017 HERBICH, J. B. 1960 (Jun). "Analysis of High-Speed Movies of a Model Pump," Report No. 277-M-11, Lehigh University, Fritz Engineering Laboratory, Bethlehem, Pa.

Investigations concerning particle movement through a scale model of a hopper dredge pump are presented. The 1:8-scale model is from a pump design presently in use on the U. S. Army Corps of Engineers dredge "Essayons." The intent of these studies is to observe how concentrations of silt and clay will behave in a pump designed for sand-water mixtures. In order to observe and photograph the flow, a transparent plexiglas volute chamber and suction side head were installed instead of a cast steel casing. One-eighth-inch-diameter plastic balls (specific gravity 1.19) represent soil particles of similar density. The side and front of the volute were photographed simultaneously at the rate of 6,000 frames per second. Two conditions were tested: (1) constant discharge of 1,000 gallons per minute while pump speed was varied, and (2) constant speed of 1,440 rpm under various discharge rates. Measurement of average discharge angles was a key objective in understanding

is to suck up sediments (usually by a Californian type head) and discharge them through a long boom to points away from the dredged channel for current dispersal. Although the few of these vessels in operation in Venezuela and elsewhere have had great success, there is a lag in widespread adoption. The largest vessel, the four-pump ZULIA, is the largest earth moving machine in history. It was built specifically to clear an entrance to Lake Maracaibo. Four 32-inch dredge pumps provide suction, and the material is discharged through a boom almost 400 feet long and a 57-inch pipe (at 60 feet above the water surface). Twelve thousand horsepower pumping capability is available. Advantages of this technique include: ease of moving the boom out of traffic, no need for floating pipelines or cables and winches, wide adaptability to sand moving problems, and economical advantages. Production costs are often less than one-fourth those of other methods. River cross sectional areas are maintained but material is redistributed by boom sidecasting.

1014 HEAD, V. P. and DURST, R. E. 1957 (Dec). "Stock Slurry Hydraulics," Technical Association of the Pulp and Paper Industry, TAPPI, Vol 40, No. 12, pp 931-936.

Pipe friction is discussed in relation to paperstock slurry flow. Five recent events have helped allow correlation of friction data for paperstocks: (1) development of a new device to accurately test yield stress; (2) development of simple microscopic method to obtain average river length; (3) publication of data on pipe friction tests in 12.47-inch pipe; (4) publication of relative roughness data on 2-inch pipes; and (5) review of personal files of the late Edgar Buckingham on dimensional analysis and non-Newtonian flow. Of two properties previously proposed for consideration (yield stress and slope viscosity), yield stress is found to be a vital element of fibrous slurry hydraulics, but slope viscosity is not a necessary consideration. A kinematic equivalent of yield stress (M) is developed; it is a constant of a particular slurry at a particular concentration, but has units of length divided by time and thus replaces velocity in the more familiar parameters of time fluid flow. Major sections of this article contain dimensional analyses of M , friction loss calculations and examples, and descriptions of seven fibrous slurry sample tests. More testing is suggested for obtaining influences of pipe roughness, particularly for 3-inch rough cast iron and smooth stainless pipes.

1015 HEIBERG, E. R. 1975 (Sep). "A Dredging Challenge: New Orleans Waterway," World Dredging and Marine Construction, Vol 11, No. 10, pp 58-61.

The New Orleans District of the U. S. Army Corps of Engineers carries out the largest dredging program in the nation to allow commerce at three deepwater ports in Louisiana and along the Gulf Intracoastal Waterway, stretching from Florida to southern Texas. Navigation is a way of life in Louisiana. International shipping and barge traffic make the Port of New Orleans the state's largest industry. Throughout the District there are 2,800 miles of navigable channels (405 miles are deep

spherical particle. The model employs a frictionless envelope of fluid. The boundary value problem to be solved for the disturbed flow involves the creeping motion equations for an incompressible fluid. The relationship derived between relative viscosity and solids concentation agrees well with published data for a wide concentration range, and the introduction of empirical constants is not needed. The model appears to be appropriate for further theoretical study and for furnishing a basis upon which to develop empirical correlation equations for various rheological properties. The mathematical model does not, however, agree with the well-known Einstein formula when considering very dilute suspensions. Reasons for this variation are given.

1012 HARRIS, J. W. 1963. "Means and Methods of Inducing Sediment Deposition and Removal," Proceedings, Federal Inter-Agency Sedimentation Conference, Miscellaneous Publication No. 970, Paper No. 69, pp 669-674.

Maintenance dredging in Savannah Harbor currently is needed annually on an almost continuous basis to remove about 7,000,000 cubic yards of silt and clay at a cost of over $1 million. After the harbor was deepended in 1947-1948 to 34 feet, shoaling shifted upstream and concentrated in shipping channels adjacent to the city of Savannah, where limited areas are available for spoil disposal. The use of model studies was employed to find a method of reducing shoaling in the channels and inducing the majority of sedimentation in a "trap" that would be located as close as possible to spoil disposal areas, and, preferably, not in the channel. A prototype model using scale ratios of 1:800 horizontally and 1:80 vertically was constructed. After numerous tests and sediment trap configurations, the final satisfactory design incorporated a tide gate, would accomodate future harbor deepening, and gave evidence that 89 percent of shoaling would be induced in the sediment trap (basin). The final sediment trap would be 600 feet wide, 40 feet deep, and about 2 miles long, with a 300-foot-wide entrance, having a depth of 34 feet. A 500-foot-wide gate would permit flood flows but retain ebb flows. Other advantages of the system are: (1) shorter dredge discharge pipelines (which could be fixed in place to save labor costs), (2) dredging would be out of the channel, and (3) continuous dredging is not needed, thereby allowing better consolidation of the "fluff" (unconsolidated particles).

1013 HAYWARD, H. G. A. 1962. "Sidecast (Boom) Dredging -- Foreign Experience and Local Application," Bulletin, Permanent International Association of Navigation Congresses, Vol 36, No. 4, pp 35-64.

In the United States presently, only 10 percent of ports can handle the deep draft super tankers (40,000 deadweight tons or more), and many facilities are in need of economical ways to improve sand or silt dredging production. One approach to solving these problems and clear shoaled areas is by the use of boom-type vessels. Today, there are several of these in use; their capacity is immense (up to 57 million cubic yards annually in one instance). The principle of operation basically

This article gives further explanation and support to one published by W. B. Gregory in Mechanical Engineering (49(6):609-616), in which apparently contradictory conclusions were reached. It further verifies that no anomalies exist in Gregory's data, and brings out additional deductions on loss of head in a pipe carrying muddy water. The experiments reported herein used cast-iron pipe and fine material in suspension, varying from 0 to 35 percent by weight. The immediate unforeseen result, after the cast-iron pipe was placed in service with muddy water, was that head losses were found reduced to those expected and observed in smooth pipe. These results are explained by suggesting that a thin deposit on the rough inner walls of the pipe came about from the material in suspension, and that this had the effect of transforming the rough surface to a practically smooth surface. Analogous observations have been made in pumping petroleum oils. Much of this article is devoted to theoretical considerations of various formulas for explaining the pumping results, including those from using straight pipes and elbows with the various solids concentrations.

1010 HANSEN, RAY S. 1971. "Dredging: Problems and Remedies," Limnos, Vol 4, No. 1, pp 3-12.

The Corps of Engineers recently recommended that most dumping of harbor dredgings in the Great Lakes be stopped. The factors that prompted taking this step are described. Over 115 harbors on the Great Lakes are dredged almost annually to maintain suitable depth for cargo vessels; each inch of shoaling reduces cargo capacity of the average "Laker" by about 100 tons. The government had resisted changing methods because of increased costs and absence of evidence concerning adverse effects of open-lake dumping (at about 100 dumping areas in the Great Lakes). Many people believed that the harbor sediments were too polluted to continue being dumped, and an in-depth examination of the many types of potential effects was conducted. The Corps, other agencies, private companies, and universities undertook 2 years of studies at numerous Great Lake sites. Project costs were $8 million. Among the eight major conclusions reached are that: (1) each harbor presents its own unique problems related to the drainage basin, sediments, and availability of disposal areas: (2) the dredging does not harm water quality or the environment in the harbors where it takes place (sometimes it is beneficial); (3) effects of dumping in the open lake are not yet fully known; (4) any treatment of dredged material is too costly; (5) disposal behind closed dikes is less costly, and the areas may eventually be used for other purposes; and (6) dredging procedures and equipment improvements can be made. The ultimate recommendation is to use diked disposal during a 10-year test period.

1011 HAPPEL, J. 1957 (Nov). "Viscosity of Suspensions of Uniform Spheres," Journal, Applied Physics, Vol 28, No. 11, pp 1288-1292.

A theoretical idealization of the complicated boundary value problem (viscosity) presented by a random assemblage of spherical particles is described. It is assumed that the suspension consists of a number of spherical cells, at the center of each of which is placed one

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1037 JASKULSKI, G. B. 1980 (Jul). "The Application of Underwater Dredge Pumps," World Dredging and Marine Construction, Vol 16, No. 7, pp 7-10.

The underwater ladder pump on dredges has gained tremendous favor throughout the world for mining applications, pipeline river crossings, and maintenance dredging, especially where unusually deep dredging conditions prevail. Because of friction and entrance losses as well as losses from entrained solids, available suction pressure rapidly diminishes with depth for pumps mounted on the vessel. However, pumps mounted underwater on the ladder have numerous advantages leading to a greater available "net positive suction head." First, suction losses are minimized and atmospheric pressure is utilized to the maximum for delivery of solids to an underwater pump. Under this situation, destructive effects of cavitation are eliminated. Another advantage is that the main pump can operate at a higher speed with smaller diameter impeller, using less expensive reduction gear, smaller shafts and bearings, and result in cost savings and less maintenance cost. The preferable drive assembly (of several possibilities) is direct electric drive with a waterproof seal to the motor housing. As an example of a recent installation of such equipment, a discussion is presented on the dredge "Mindi," owned by the Panama Canal Company. The "Mindi" has a 32-inch suction and 28-inch discharge. The ladder pump installed has a rating of 900 horsepower.

1038 JEPSKY, J. 1982 (May). "System for Automatic Positioning of Dredges Based on Radar Techniques," World Dredging and Marine Construction, Vol 18, No. 5, pp 16-20.

New radar ranging instruments permit more accurate positioning systems for the dredging industry than do transponder systems. One such system known as PRANS (Precise Radar Navigation and Dredging System) is described in this article. The instrumentation has a range accuracy of 6 inches r.m.s. at distances up to 10 miles, thereby permitting positioning accuracies of 5 feet r.m.s. to be maintained. Most information presented relates to general system performance, radar modifications used, linear amplifier, constant fraction discriminator, and retroreflectors. With multiple use of retroreflectors (three or more), operations may continue without signal blockage from passing vessels; this technique also improves position accuracy by a factor of two. The display components of the system give the following information in real time: (1) deviation from the intended track or cut; (2) distance to end of vessel track or cut; (3) vessel attitude relative to intended track (crab angle); (4) vessel speed over the bottom; (5) range/range data; and (6) X-Y coordinates. Advantages (design criteria) include hands-off operation after initial startup, all electronics onboard, simple restarting or reprogramming, and built-in fail-safe and self-testing diagnostics.

1039 JUSTICE, R. 1980 (Mar). "Automated Position Fixing at the Port of Miami, Florida," World Dredging and Marine Construction, Vol 16, No. 3, pp 7-9.

One of the largest port modification projects in the United States is now in progress at Miami, Florida. It involves several phases to expand cargo and passenger handling facilities through the year 2000. The 13,000-foot outer harbor entrance is being widened by 200 feet, and 15,000 feet of the south channel is being modified for marginal wharves. In all, about 13 million cubic yards of sand, silt, and limestone require dredging. The materials are to be used to form an additional operations area or transported to an upland disposal site. Hydraulic, cutterhead pipeline dredges and a heavy duty clamshell dredge carry out the work. For success of the entire enterprise, there is a need for speed, reliability, and proven accuracy. Therefore the Tellurometer MR101 microwave dynamic position fixing system is being used to effect a near total state of automation. This system is able to negotiate repeatable accuracies of less than 1 meter over ranges up to 100 kilometers. Its advantages include no tuning or calibration and no particular operating skill other than familiarity with front panel controls. Installation and maintenance also are simplified by use of easily removable circuit boards. Several vessels (up to six) can use one set of remote units onshore. Automatic data processing is carried out by an internal microprocessor. The Miami project uses the system to set buoys, continuously monitor dredging, provide pre- and postdredging cross-sectional data to estimate fill quantities, and to position other survey boats.

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1040 KARELIN, N. T. 1965 (Jun). "Some Problems of Hydraulic Transportation of Solid Materials Through Pipes," Journal, Mines, Metals and Fuels, Vol 13, pp 187-194.

The application of hydraulic transport in mining is continuously and rapidly expanding, even for underground mining. Hydraulic transport of ore by gravity was used as early as 1830 in the U.S.S.R. and in 1852 in California. Presently, it is used in pipeline systems to move coal as much as 173 km in the U.S.A. Economic calculations show that hydraulic transport from existing mines can save about 50 percent over locomotive haulage or conveyors. Five studies in the U.S.S.R. are considering hydraulic transport for distances from 10 to 1900 km. In designing a hydraulic transport system, the key item to be determined must be average velocity over the cross section because other parameters depend on it. Critical velocity is defined as that minimum velocity at which all particles travel in suspension. Below this, jamming occurs; above it, specific energy losses increase. Equations are derived for determining critical velocity, head loss, and other parameters. However, the case of open-type, gravity systems is emphasized in examples. Theories on hydraulic gradient are presented, but they do not account for all properties of a two-phase stream. In most cases, it has been shown that only empirical formulas for determining hydraulic gradient are practical. A table is presented giving critical velocities of clay, clay and sand, sand and gravel, and coal, in pipe diameters ranging in size from 100 to 600 mm. The presence of air pockets in pipes, and their effects, also are discussed.

1041 KARLIN, B. I. ET AL. 1969 (Jun). "Computation of Governing Parameter for Automated Suction-Dredge Programming," Translated from Gidrotekhnicheskoe Stroitel'stvo, Vol 6, pp 29-33.

Automatic operation of suction dredges for hydraulic filling is being developed. The first step has been development of automatic systems for starting, stopping, prevention of loss of vacuum, and for mechanical safety. The next step will be complete automation of suction-dredge operation by developing an "autoloader" which completely takes over the operator's functions during the dredging. The programming of the autoloader must be based on familiarity with the technological process. This article describes several tests and relationships developed while experimenting with operating conditions for a suction dredge type 300-40 in the U.S.S.R. The optimum operating condition was found to be that at which maximum excavated soil output took place with minimum electric power input (per cubic meter of soil). One conclusion is that the hydraulic mix specific gravity is the only defining programming parameter (independent variable) needed for the automatic suction dredge.

1042 KAUFMANN, K. P. 1965. "Design Trends in Dredging Machinery," Shipbuilding and Shipping Record, pp 46-48.

A continuing evolution in design of dredge equipment is occurring because of the wider variety of underwater excavating projects being planned and the need to raise efficiency, reduce fuel costs, and lower overall operating expenses. This article gives a broad overview of innovations in dredge equipment design. One new concept is the totally portable package of hydraulic pipeline dredges, ranging in size from 8- to 20-inch discharge pipe diameter. Another new dredge design is for work in narrow or confined waterways; the ladder swings independent of the hull, and it works on a 4-speed system. Submarine dredges also are being developed, suspended by platforms extending above the surface. These will be particularly applicable for tunnel building. Clamshell and bucket-ladder dredges are being modified to dredge to 200 feet. Key components of dredging systems also are covered with respect to new designs; among these are pumps (to reduce cavitation), shock absorbing features, gas-turbine power plants, flow and density meters, and specialized dredges (for example, the dustpan dredge for shoal removal).

1043 KAWASAKI, H. ET AL. 1972 (Aug). "Two Underwater Bulldozer Systems," Ocean Industry, Vol 7, No. 8, pp 34-35.

Two new systems are presented which hold promise for providing safer and more efficient operations than using divers or dredges. These are a shallow (up to 5 m) type and a deep (5 to 60 m) type bulldozing system. The shallow system consists of a power barge, an unmanned bulldozer, and an S-shaped connecting bar. The catamaran power barge has a diesel driven hydraulic power unit, air compressor, and control room. The operator views a sign pole on the surface giving inclination, depth, and direction of the bulldozer, as well as blade position. The bulldozer can be floated to the work site, and floatation tanks regulate the operating weight (0 to 13 tons) once it is under water. Tabulated data gives specifications for the barge, bulldozer, and power equipment. The deepwater type system consists of a larger bulldozer (32 tons on land), a power barge, and a connecting cable. Data needed for proper deep operations include knowledge of the seafloor profile, posture, direction, and blade displacement. Poor visibility makes these factors difficult to determine. Details are presented on how these factors are transmitted to the surface and how steering is controlled. As with the smaller system, the large one also is floatable for transport. Speed of the large system is 0 to 3 km/hr, forward or reverse.

1044 KAZANSKIJ, I. 1968. "Application of Results from the Research of Hydraulic Transport for Automatic Control," Proceedings, World Dredging Conference, WODCON II, pp 193-223.

Several aspects of hydraulic transport and parameter measuring techniques are described with respect to automatic control of suction dredgers. A review of past research on hydraulic transport is given, showing shortcomings of certain approaches and derived formulas. A newly designed instrument known as the "induction measure gauge" for hydraulic transport is described. Instead of using a single pair of electrodes, this system uses numerous pairs to get a better estimate of

flow velocities by mixtures in a number of layers (vertically) in a horizontal pipe. After a detailed explanation of theory and assumptions applicable to practical studies, experiments are discussed which were performed to verify formulas for pressure loss and critical velocity, to define deformation of pump characteristics for various soils, and to serve as basic research on kinematic structure. The new induction transmitter was used for velocity profiling and to study deformation of velocity profile curves. Eleven natural and sorted types of sand were used at from five to eight values of concentration and five velocities of between 1 to 6 meters per second. Relations for all results are provided, but further experiments are suggested. The new induction gauge performed quite well, including during a field test on a suction dredger to assist with automatic control.

1045 KERSSENS, P. J. M. 1980 (Oct). "New Developments in Suspended Sediment Research; Theme 2: River Sedimentation and Dredging," Delft Hydraulics Laboratory, Publication No. 237.

New research methods developed by the Delft Hydraulics Laboratory are discussed. These include two mathematical simulation models and two devices for measuring suspended sediments. The first model (SUSED) is used to predict bed-level changes on rivers without tidal influence, especially as a result of human influence on natural river conditions. An example of SUSED application is on the Serang River in Indonesia, where a diversion canal was built to improve flood control. Mean bed level changes per year in various branches and for several scenarios were calculated. The second model (SUTRENCH) predicts sedimentation rates in dredged trenches. An example from a Netherlands estuary used measured changes along 5-m intervals and time increments of 2 hours for 2 months. Both the predicted amount of deposited material and the time-dependent development of the bed profile were satisfactory when comparing measurements with model predictions. The future pursuits of the Laboratory in the field of modeling also are reviewed. The new suspended sediment samplers are an acoustic Doppler meter type and a pump filter sampler which obtains a large enough sample (0.05 cubic meters) to improve accuracy in sediment concentration measurements. Both instruments are designed for use in unsteady flow conditions.

1046 KHARIN, A. I. and KOTOVSKII, V. I. 1971 (Nov). "Conversion of Operating Characteristics of Suction Dredges from Water to Slurry," Translated from Gidrotekhnicheskoe Stroitel'stvo, Vol 11, pp 30-33.

For converting head, power, and efficiency characteristics of suction dredges from pumping water to slurry, published recommendations are contradictory and in error. This article presents results of laboratory and field investigations for improved conversion formulas. Tests were conducted on four dredges working in gravel-sand and in gravelly, sandy, sandy loam, and loamy soils. Test conditions involved (1) no operations in the range of cavitation, (2) detailed knowledge of the pumped materials, and (3) sufficiently accurate measurement methods.

Formulas are derived, and test data are presented in tabular and graphic form. Whe slurries with very fine particles are pumped, the increase in head is directly proportional to the increase in specific gravity of the slurry. With an increase in particle size, the transportability coefficient increases, as does the pressure coefficient. Several theoretical studies gave different results; these are reviewed. This study ascertains that the particle size of the slurry solid phase exerts a deciding influence on the dredge's head, and that this influence primarily is related to motion trajectories in the impeller ducts and pump outlet. Another major finding is that power increases in direct proportion to a slurry's specific gravity. With the proposed conversion method, it is possible to compute working characteristics of suction dredges, pumping slurries with average particle size up to 30 mm, with an accuracy sufficient for practical applications.

1047 KISS, S. 1975 (Apr). "Hydraulic Dredging Work Efficiency Evaluated," World Dredging and Marine Construction, Vol 11, No. 5, pp 26-27.

A brief case history from a highway construction project is given of a cutter suction dredge working through deep layers of muck which had a high "slide-in" tendency. Two dredges, a 10-inch and a 14-inch, experienced delayed operations because of original miscalculations of slide-in volume, repairs, cutterhead cleaning, and moving time. Total lost time on the 10-inch dredge was 20 percent; that for the 14-inch dredge was 26 percent. Sand generally slides in on a slope of from 1:3 to 1:5, depending on the grain of the sand. On the other hand, dredging muck to 50 feet results in slide-in from 500 feet away, a 1:10 slope. Extra expressed force on surcharged areas in the dredging vicinity also contributed to the need to dredge four times as much muck and sand as originally calculated.

1048 KLIEN, M. 1977 (Apr). "Side Scan Sonar," Offshore Services, Vol 10, No. 4, pp 67-75.

The use of side scan sonar is accelerating throughout the world for diverse applications. Although first developed during World War II, nonmilitary uses began about 1958. More widespread use of medium-priced units began in the late 1960's. Side scan sonar systems use a towed device called a "fish" which emits high frequency, high intensity sound pulsed to either side and below a towing vessel. The sound beams are narrow horizontally and wide in the vertical plane. The pulses (50 microseconds to 1 millisecond) echo off objects on the seafloor and return. They are converted to electrical signals and recorded, sometimes along with echo sounding or subbottom profiling signals. The resolution of the objects "seen" with these systems can be as little as a few centimeters. Modern systems are portable and free from a ship's motion. Nine typical applications are given as examples, ranging from pipeline surveys to finding submerged shipwrecks and natural gas seeps. Sophisticated circuits have been developed recently to vary the gain to improve signal return and record quality, and thereby produce uniformity.

These systems also can be connected to a computer for data reduction, or to event recorders. New electronic reversal techniques allow production of "positive" sonar images. Problems which remain to be worked out include low speed transmission, high attenuation rate, ray bending, scale correcting, target recognition, and improved graphic recording.

1049 KLEINBLOESEM, W. C. H. and DEGAST, J. 1980 (Oct). "Dredged Silt in Rotterdam Looks Valuable," Proceedings, World Dredging Conference, WODCON IX, pp 273-285.

Maintenance dredging of Rotterdam Harbor (fed by the Rhine and Meuse Rivers), results in a yield of about 6 million cubic meters of fine clay and silt material annually. Storage on land and possible uses for the material are described with the following two aims: (1) maximum storage per surface unit area in the shortest time at the lowest cost; and (2) selection of a qualitatively good (environmentally suitable) site. For many years, techniques of storage, environmental effects, and alternatives for "ripening" or "maturing" dredged material have been studied. Layered disposal within dikes (of layers 1.0 to 1.5 m thick), dewatering, conversion to ripened, solid soil, and adding another layer has been an effective disposal method from dredging/pumping. Cycle time between layers has been 1.5 to 2 years. Several layouts and designs of such systems are shown. A formula is derived for calculating storage capacity, and design criteria are given for dike construction, filling, discharge, and dewatering. Past investigations into environmental effects of disposal or using the material for other projects are discussed, especially with regard to pollutants (such as heavy metals, oil, and pesticides) and salt. Four possible uses are elaborated upon: (1) clay for construction purposes (dikes, etc.); (2) fill for "green strips" (forest plantings); (3) use in coarse ceramics (20 to 50 percent in bricks); and (4) protection against erosion when mixed with gravel.

1050 KOBERNIK, S. G. 1968 (Oct). "Comments on Technical Specifications and Standards (TUIN) for the Hydraulic Transport of Granular Material Through Steel Pipes," Translated from Gidrotekhnicheskoe Stroitel'stvo, Vol 10, pp 38-39.

This article is a response to an earlier publication which gives equations for determining the critical velocities and head losses in the hydraulic transport of solids through pipes. Indications are that technical specifications and standards (based on four data sets) as drawn up cannot be recommended for practical calculations. It is shown that several equations are in error, and it is pointed out that at least one excellent set of data has been improperly omitted. The equation for giving specific head loss in the transport of a hydraulic mixture is shown to be inappropriate when considering transport of sand with mean diameters of between 0.15 and 0.25 mm. New equations are provided which take into account the nonhomogeneous nature of the hydraulic mixtures.

1051 KOFANOV, V. I. 1964 (Jul). "Heat Transfer and Hydraulic Resistance in Flowing Liquid Suspensions in Pipes," International Chemical Engineer, Vol 4, No. 3, pp 426-430.

Based on present investigations and experimental data, as well as data of other researchers, relationships are obtained for heat transfer and hydraulic resistance for liquid suspension flow in pipes. The equations derived are dimensionless and satisfy the experimental data with an accuracy of ±10 percent in the given range of parameter variation. A detailed description is presented for the apparatus used in the experiments; methods of measuring temperature, pressure, electromotive force, mass flow, and other parameters are given. Formulas are presented for calculating heat transfer coefficients, viscosity, and thermal conductivity for suspensions, along with a final integrated design equation. The suspensions tested included water-chalk, water-coal, water-sand, water-aluminum, and water-iron. All tests were calibrated by preceding and subsequent runs with water. Experimental data and use of the design equation appear applicable to pipe diameters ranging from 12.5 to 40.9 mm in diameter. The major conclusion is that, within the investigated range of parameter variation, liquid suspensions generally behave like ordinary liquids when a correction is made for the effect of the presence of solid particles, for the viscosity, thermal conductivity, and other physical properties.

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1052 LAARMAN, J. B. 1972. "Walking Cutter Dredging Platform," <u>Ports and Dredging</u>, No. 2, pp 21-24.

A new concept for an offshore cutter suction dredging platform is described. It was developed and patented by I.H.C. Holland. The L-shaped pontoon platform is supported on three pairs of "walking spuds" and was designed for high production rates in hard soils, at depths up to 25 m, and in considerable currents and swells. It is especially valuable for work in severe conditions such as encountered in the North Sea. Weight constraints affect the cost effectiveness of such designs. The system can dredge a cut 41 m wide and can move forward at 8.8 m/hour. It normally produces solids concentrations of 50 to 60 percent, but up to 80 percent can be achieved in soft materials. Reduced downtime is realized by the ability to withstand (while not dredging) currents of 5.5 km/hour, wave heights of 7 m, and wind velocity of 30 m/sec. Also, two men can change the cutter in 12.5 minutes by direct access through the ladder, which also houses the dredge pump at its midpoint. The new platform's performance is compared to a conventional cutter with spuds and/or swing wires in several tables and charts. Annual production of the platform can be as high as 2.48 million cubic meters while that for a dredger with spuds is only 0.46 million cubic meters. Characteristics of the system's production, dredging depth, mobility, dimensions, machinery, additional facilities, and transportability are discussed. The system is limited in narrow areas or when long distances need to be covered relatively quickly. Cost is most dependent on final weight.

1053 LAIRD, W. M. 1957 (Jan). "Slurry and Suspension Transport: Basic Flow Studies on Bingham Plastic Fluids," <u>Industrial and Engineering Chemistry</u>, Vol 49, No. 1, pp 138-141.

A mathematical derivation is given for the flow of oilfield drilling mud (a typical Bingham plastic) in an annular section (between drill pipe and well casing or bore hole). The equation is complex and requires numerical solution, but it can be simplified by making certain assumptions to give an approximate picture of annular flow without requiring laborious calculations. The justification of applying the unsimplified equation is dictated by the accuracy needed. If flow rates are fairly high, an approximation probably will suffice; however, if they are low, an exact solution should be obtained. An exemplary graph emphasizes this point. The graph depicts laminar pressure drop versus rate of flow in an annular conduit for Bingham plastic and Newtonian liquid; it also shows results of the approximation equation and the exact equation.

1054 LAMBSON, R. E. 1975 (May). "Modern Aids to Dredge Positioning," <u>World Dredging and Marine Construction</u>, Vol 11, No. 8, pp 38-39.

Electronic technology now helps solve many of the positioning problems faced by dredge masters. The Mini-Ranger III is a modular

system built by Motorola to assist dredging operations. The basic system consists of two unattended shore-based reference stations placed at predetermined locations. A signal is received by the compact shipboard equipment; this provides the operator with known distances to two points. These data can be provided in a number of ways including binary coded decimal format for peripheral equipment. By converting range-range information into X-Y coordinate data, several valuable options can be applied. Among these are steering indicators to allow helmsmen to steer accurate prerecorded courses per incremental offsets. X-Y plotters can be used to provide real time plots of actual dredge position; depth sounding information can be correlated and plotted concomitantly. Cost effectiveness is a major determining factor in selecting a system; this system has several advantages in this regard. In areas where two reference points do not give adequate coverage, up to sixteen shore stations can be used. Multiuser capability also can be implemented, allowing several dredges to operate up to 20 nautical miles away. Special antennas can extend the operating range to 100 miles. The instrument has a built-in self-test module. When the phenomenon of wave cancellation is encountered, the system can switch automatically to another antenna and allow continued operation.

1055 LAMOTTE, C. 1970 (Oct). "Deepsea Ventures' Pilot Run is Successful," Ocean Industry, Vol 5, No. 10, pp 7-13.

The "Deepsea Miner" is a 320-foot cargo ship converted to a deepsea dredger in order to mine manganese nodules. Deepsea Ventures, Inc., a Tenneco, Inc., subsidiary, is in the forefront of developing capabilities for combined nodule dredging/processing from depths up to 18,000 to 20,000 feet in the Pacific. This article describes the initial equipment development and testing at a depth of up to 3,000 feet off the Florida coast. After original testing in 1970, the objective is to have the full range of deepsea equipment in operation in 1974 and begin producing 1 million tons of nodules annually in 1975. Tenneco, Inc., already has $15-18 million invested, but the full-scale project will require financing of $150-200 million by an international consortium. The initial idea involved development of a special dredge head with rake to pick up nodules 2 to 4 inches in diameter and feed them to an intake fed by compressed air. The air, nodules, and water would flow up a specially weighted and flexibly coupled string of 9 5/8-inch drill riser casing to an onboard separator. All systems worked, but television transmission from the underwater camera monitoring the dredge head was weak. On July 30, the excited message was relayed to headquarters: "The nodules are coming up the pipe!" In the future, there will be much contention for the mining of deep ocean minerals.

1056 LANGEFORS, U. and KIHLSTROM, B. 1967. "The Modern Technique of Rock Blasting," Almqvist & Wiksells Boktryckeri Aktiebolag, Uppsala.

Rock blasting has evolved over the years from a manual occupation in which long experience, personal skill, and intuition were dominant, into a technical science for which the fundamental concepts can be taught

:o students, engineers, and workers. This book presents an introduction :o the field of rock blasting as it has been built up in the mining and engineering practices through research, theory, field tests, and application. Methods, tools, equipment, safety procedures, types of explosive, and modern instrumentation are covered. Previous research works are frequently cited. Underwater blasting and blasting through overburden are given comprehensive coverage in a final chapter. Principle parts of the text (after an explanation of the mechanics of breakage) include: (1) calculation of charge; (2) loading of drill holes; (3) bench blasting using ammonium nitrate explosives; (4) short-delay blasting and multiple row rounds; (5) tunnel blasting; (6) ground vibrations; and (7) smooth blasting with presplitting. Among the loading techniques described are rod tamping, pneumatic loading, the pressure water loader, and underwater loading. Safety measures in ignition cover leakage of current, static electricity, lightning, power lines, and radio frequencies. Photographs and diagrams add significantly to the discussions.

1057 LEIMDORFER, P. 1975 (Sep). "Quick Assessment of the Bearing Capacity of Soils," Dock and Harbour Authority, Vol 56, No. 659, pp 160-165.

When depositing material for reclamation purposes, the question often arises of whether or not the new land possesses the bearing capacity to support the heavy load of the future, as well as any surcharge or dynamic load. In order to avoid problems with subsidence or earth slips, engineers may use the graphical method presented herein to approximate requirements for control of ground stability. This method is especially applicable to port facilities, airports, or other types of loading terminals. Although mathematical derivations that are time consuming and complex are available, and are discussed, the soil mechanics problems are simplified to three major loading configurations: (1) that of a triangular load descending toward the center of a "slip circle," (2) that of a triangular load ascending toward the center of a circle, and (3) that of a uniformly distributed constant load. Active turning moments, reactive forces, safety factors, and kinds of stresses and loads are discussed. Several practical application examples are provided.

1058 LEVIN, H. and GEPHARD, M. 1959 (May). "What Slick Coatings Will Do for Flow in Small Diameter Lines," Pipeline Industry, pp 32-34.

Laboratory tests are described showing that friction loss for internally coated pipe is much less than for either new uncoated pipe or used pitted pipe. Fluid tests were conducted in 30-foot sections of 2-inch pipe. Coated pipe had an internal, thin-film coating of plastic (five coats baked phenolic followed by three coats of thermosetting phenolic modified epoxy). Measurements included head losses, temperatures, and flow rates. Data were recorded when steady-state conditions were reached. In the laminar flow region, an oil was used as fluid; water was used in the turbulent flow region. Experimental data are given in two tables; most data were generated for the turbulent flow region. From the data, friction factors (F) were calculated using the

nning equation, and were correlated with Reynolds number. Williams d Hazen coefficients (C factors) also were tabulated. Among the findgs are: (1) friction losses in new pipe are 10 percent above those in ated pipe at the low end of the turbulent region, 17 percent above in e middle turbulent region, and 20 percent above in the upper turbulent gion; (2) effectiveness of coating increases with increasing Reynolds mber, and is a function of both smoothness and thickness; (3) in the minar flow region, flow resistance is independent of the nature of the ternal pipe surface; and (4) maximum reduction in flow resistance is hieved by a coating of maximum smoothness and minimum thickness. Apications of coatings result in reduced pumping costs and increased roughput.

59 LINFORD, A. 1970 (Apr). "Manchester Ship Canal: Design of Pumping Installation for Dredged Sand and Silt," Civil Engineering and Public Works Review, Vol 65, No. 765, pp 399-401.

Material dredged from the Manchester Ship Canal has been pumped hore from barges to a large deposit area of about 400 acres (at a disnce of up to 2 miles). The steam-driven pumping station is 57 years d and its useful life is ended. To prepare specifications for new edge pumps, pressure loss testing in the laboratory and field condions was necessary. The material consisted of one of two types of urries: silt and water or sand and water. The silt particles were tremely fine; 90 percent or more (by weight) could pass through the itish Standard No. 350 sieve. This is the finest, having apertures of ly 45 microns. The sand was much coarser; even with the finest sand, least 50 percent was retained on a No. 100 sieve, with apertures of 15 mm. The silt slurry was found to behave like a non-Newtonian uid, that is, to have an initial yield stress. However, even at ghest solids concentrations, it was found that the yield stress was w enough to be ignored, resulting in a "homogeneous mixture." The ntrolling factor for sand/water calculations was the drag coefficient. om several assumptions and calculations, it was found that sand in the mped slurry would be 7.14 percent by volume. Site testing using pipe to 19 inches in diameter confirmed results predicted from laboratory sts and calculations regarding head loss, percentage concentration of ilds, and velocity for various pipe sizes. Based on all data, new -inch pumps of 900 BHP each and auxiliary diesel-electric drive equipnt were ordered.

60 LINSSEN, J. G. T. 1980 (Oct). "Economic Aspects of the Dredging Industry," Proceedings, World Dredging Conference, WODCON IX, pp 75-109.

The capital-intensive dredging industry is one with high risks, d it survives under many unfavorable conditions. The overview presnted herein describes economic problems, legal situations, and intertional factors that are of importance to both dredging contractors and eir employers. The dredging industry has developed rapidly in recent ars; equipment, technology, demand for better skills, and the size and

ılexity of jobs have all increased. Dredgers are highly dependent, :ver, on decisions of employers, who often postpone or cancel proj-;. This necessitates keeping equipment in reserve. By necessity, lging has become an international business because of the irregular- of the work. Among the reasons that dredgers have trouble adapting ›eriodic increases in demand are that new plant construction takes a ; time (1 to 2 years), and the equipment held in reserve is generally the most modern and efficient available. Flexibility in this regard :s through formation of joint ventures, subcontracts, or charters. ›etition among dredging companies is keen, but some countries restrict lgers to those from in the state (or at least to equipment built :ein). As in the United States, dredging companies often must com-: with units of their own employer--government agencies with their dredges. Some governments support dredgers in various ways. The ler system used to botain dredging contracts is discussed at some ;th. Three types of tenders are the public (or open), selected (or trictive), and privately negotiated (or sole source). Collusion in lering is not uncommon. Discussions of various risks involved con-le this article.

1 LIPTAK, B. G. 1964 (Apr). "A Guide to the Selection of Control Valves for Slurry and Viscous Services," Chemical Engineering, Vol 71, No. 8, pp 185-192.

Graphic and tabular data are presented to assist in the selection a particular valve for application in slurry or viscous flow condi-ns. Charts are shown, each with a number of curves representing ious valve types, for: (1) cost--with dollars plotted against valve e in inches; (2) capacity--with valve capacity in gallons per minute 1 pound per square inch pressure drop plotted against valve size; and control--with stroke (percent lift) plotted against flow (as percent naximum). In a matrix table, 21 characteristics of valves are given 12 different valve types ranging from pinch clamp to split body to ball types. Seven categories of valve types are discussed, giving antages and disadvantages as well as the action of the valve. The en categories include pinch, diaphragm, split body, angle, "V" ball, erting, and miscellaneous. The miscellaneous category encompasses es such as the standard butterfly, slide gate, ball valve with cage der, and annular-sleeve slide valve. A control method, using pumps, o is described for slurries that settle rapidly and flow at very low es, thereby tending to block lines.

2 LITVINENKO, A. M., KOZHEVNIKOVA, E. I., and VASIL'EV, V. N. 1967 (Jul). "New Pumps for Handling Slurries with Solids," Chemical and Petroleum Engineering, Vol 7, pp 8-13.

The VNIIgidromash Institute has been carrying out an intensive earch program to standardize and develop new designs for pumps to t demanding engineering specifications. Four families of pumps are cribed: sewage pumps, wood pulp pumps, sand pumps, and dredging ps. Uses for each group are given along with new design features and

nal sizes. Emphasis is placed on the concept that, within each , a number of features can be standardized for simplification in ruction, parts supply, and repair. Sewage pumps included have deies of 2 to 1000 liters per second operating against heads of 8 to eters water, with inlet ducts up to 400 mm. Wood pulp pumps have ities of 6 to 400 liters per second operating against heads of 8 to ters water. The dredging pumps cover a delivery range of 7 to 0 cubic meters per hour operating against heads of 8 to 80 meters d. Sand pumps provide deliveries of 15 to 1800 cubic meters per operating against heads of 10 to 50 meters water. Much discussion ven on the testing and use of rubber-lined parts and special alloys xtended wear. For all grades and types of pumps, close attention een given to reliability, service life, and economical operations.

LIVINGSTON, G. F. 1959 (Dec). "Continuous Flow Prevents Slurry Settling," Chemical Engineering, Vol 66, p 88.

A diagrammatic presentation is given for a device which measures es of a slurry which must be continuously flowing or agitated to nt settling. The system has two compartments and an overflow chanback to the holding tank). Slurry is pumped from the holding tank gh a hose. When a measured batch of slurry is needed, the operator es an electric solenoid which pivots the end of the hose away from verflow channel and into one of the measuring compartments. Upon ng to a preset level, a float switch automatically deactivates the oid, allowing the discharge to flow against into the overflow chanr immediately be switched to the other compartment. The pivot arm ng the hose outlet returns to a vertical position over the overflow el by its own weight and gravity. Pilot lights indicate which oid is energized during filling operations.

LOESBERG, P. P. 1968. "A Model Navigator Based on Laser," Proceedings, World Dredging Conference, WODCON II, pp 224-230.

The Netherlands Ship Model Basin has developed a system based ipally on two beams of laser light oriented on ship models to acely determine their "momentary position" in a wave and current of 40 by 60 meters. Operation of the system is described by text number of figures. The accuracy of the system is about 0.1 perof the distance between two shore-based measuring instruments. The m operates well in daylight and may be applicable (with a larger source) to dredging or other positioning needs in areas up to by 1000 meters. Interruption of a light beam by ship passage may problem, but the system can be stopped automatically when pulses bsent, with an indicator marking that position.

LONG, E. G., JR. 1967 (Nov). "Improvements of Coastal Inlets by Sidecast Dredging," Journal, Waterways and Harbors Division, ASCE, No. WW4, pp 185-199.

The ocean shoreline along North Carolina has a sand barrier beach t 330 miles long, with 23 inlets. Thirteen of the inlets are of

AD-A157 539 DREDGING: AN ANNOTATED BIBLIOGRAPHY ON OPERATIONS EQUIPMENT AND PROCESSES..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 1985 2/4

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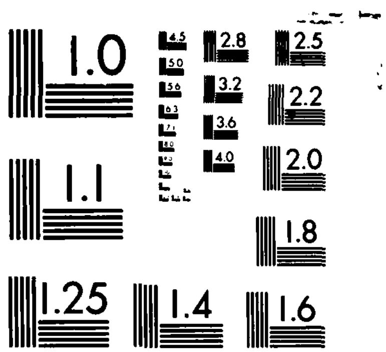

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

hydrologic origin (formed mainly by river outlets) and also are considered economically important for inclusion in the waterway transportation network. The maintenance of these inlets is especially important to the large commercial fishing fleet in the state. Because dredging with hydraulic pipeline dredges has been dangerous, hard on equipment, and expensive, planning began in 1956 for obtaining a shallow-draft, sidecasting dredge for inlet channel work. A surplus Navy vessel was converted in 1964 and was named Merritt. It is 104 feet long, has a beam of 30 feet, and a loaded draft of 4.5 feet. The hull and superstructure are steel. It possesses a 14-inch suction and 12-inch discharge dredge pump powered by a 340-horsepower diesel engine. Material can be cast 85 feet beyond the side of the dredge which produces 5 to 8 cubic yards per minute. The boom swings 180 degrees port to starboard or vice versa in 5 to 10 minutes. In actual inlet maintenance, the dredge traverses the ocean bar channel in a continuous clockwise or counterclockwise cycle. This sidecasting dredge has proven to be efficient for shallow inlet work and emergency shoal removal. Costs during the first 2 years of operation ranged from $0.27 to $0.75 per cubic yard. Theoretical minimum unit cost would be $0.18 per cubic yard. Numerous data are provided on individual dredging jobs and associated costs.

1066 LOWENSTEIN, J. G. 1959 (Jan). "For Horizontal Flow of Slurries, Design So Solids Can't Settle Out," Chemical Engineering, pp 133-135.

The class of settling slurries is discussed in relation to predicting pipe diameter needed to maintain turbulent flow in horizontal pipes. The use of the Reynolds number criterion for liquid-liquid mixtures does not apply for mixtures such as sand-water or salt-benzene. Gravity must be taken into account as well as the normally much greater density differences between liquid and solids. "Minimum velocity" is defined as the velocity below which solids settle and are not suspended by eddy currents. "Standard velocity" is that minimum velocity at which the particles of solid are suspended such that there is no concentration gradient from the top to bottom of the pipe. Between these two velocities is the "heterogeneous flow region." Equations are given for finding standard velocity and pipe diameter for particles between 50 and 500 microns in diameter, assuming certain data are available. Examples are provided for finding either slurry velocity limits or pipe size for standard velocity. A 5-scale nomograph also is supplied for facilitating calculations.

1067 LOWN, H. and WEISNER, F. J. 1959 (Mar). "Prediction of Choking Flow in Centrifugal Impellers," Journal, Basic Engineering, ASME, Paper No. 58-SA-15, pp 29-36.

An explanation is presented for predicting the maximum capacity of centrifugal impellers for gas flow. The "passage contraction ratio" thus derived is applicable to many kinds of impeller designs. A one-dimensional approach which yields exact evaluation is modified and

expanded to a three-dimensional situation in the passage throat. The method herein was applied only to impellers operating at the beginning of the transonic region; for the supersonic region, the method is unlikely to apply favorably. Several comparisons between predicted choking flow and test results (when an ideal gas is considered) were generally within 1 percent of each other. Tests and comparisons with compressible gases (primarily refrigerants with compressibility factors of 0.85 to 0.98) also showed possible use of the method, especially if small errors can be tolerated. Information given should enable prediction of choking flow with a reasonable degree of accuracy for achievement of more successful compressor designs.

1068 LOWRY, R. W. 1973 (Jan). "Men 'Moil for Mud' Down Under," World Dredging and Marine Construction, Vol 9, No. 1, pp 12-14.

Several anecdotes and a brief story tell of the difficulties encountered in dredging rock from a channel at the mouth of the Tamar River, in Tasmania, Australia's southernmost state. At the mouth of the river is a columnar basalt reef known as Shear Reef. At full tide it is covered by 40 feet of water, but just inside the channel prism line, depth drops vertically to 180 feet. With the tide coming in, the current exceeds 10 miles per hour. The incoming flow hits the vertical rock face and is directed straight up to the surface. When a small boat passes over this area, normal operation ceases, the rudder has little effect, and the sensation of being on ice or held in suspension by a jet of air is experienced. This was only one of several problems encountered by a 20-inch pipeline dredge trying to remove 2 feet of rock from the top of the basalt mass. Loaded 15,000-ton ships passing full bore on the starboard side, huge ocean swells, and numerous twisted pipelines, anchor cables, and other problems presented one disaster after another. By nothing more than sheer determination, the project was brought to completion.

1069 __________. 1973 (Oct). "Dredge Pipeline Design Formula Shown," World Dredging and Marine Construction, Vol 9, No. 12, pp 36-37.

A simple means is presented for determining how a dredge pump with pipeline and boosters can be designed to produce at the most profitable capacity. It has been used to predetermine the hydraulics, physics, and stresses in materials in the pipelines and systems of some of the world's largest dredging ventures. A single hydraulic formula and a table of data derived from the formula constitute the entire method. Examples are shown for use of the table. Pipe fittings are shown to have no effect on pipelines 20 inches or more in diameter (other than adding their length); however, for smaller pipe diameters, all fittings must be considered. The tabular method covers pipe diameters from 16 to 32 inches (inclusive), pump efficiencies of 50 to 65 percent (by 5 percent increments), and velocities of from 8 to 25 feet per second (in 0.5-foot increments to 20 fps, and 1-foot increments to 25 fps). A friction head factor for six types of material also is included. These range from light silt-mud-peat to coral shell and coarse gravel-boulders.

1070 LUNNON, R. G. 1929. "The Laws of Motion of Particles in a Fluid," <u>Transactions, Institute of Mining Engineers,</u> Vol 77, pp 65-75.

Industries which wash and separate coal and other minerals rely on only a few stated resistance laws regarding motion of particles in fluids. Rittinger's Law, for example, has beeb widely applied; others include Stokes' Law, Allen's Law, and Newton's Law, all applicable to spherical particles. Lord Rayleigh devised a means by which all cases could be shown on a single graph, that is, for spherical particles of all sizes and fluids of all densities and viscosities. The two special coefficients used are the Reynold's number (R) and the resistance coefficient. The two quantities are dimensionless numbers. Superimposed on one comprehensive log-log graph are the linear paths of Stokes', Allen's, and Newton's relations. It is pointed out that each of these three latter relations are valid for only a certain range of Reynold's number (R). For example, Stokes' Law is really true only for the lowest R values, that is, for small particles and low velocities. Irregular particles present further problems. Conditions for the laws for spherical motion are departed from in at least three ways in practical systems: particles are irregular, they are crowded together, and fluid is in turbulent motion. Experiments are discussed which have dealt with these phenomena. Fitting these conditions to various existing laws for spherical particles is described and shown to be applicable, with certain changes. New formula modifications are presented to show these changes. In summary, the article supports the concept that the Rayleigh Law of dynamic similarity can be applied to give a general solution to the problem.

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1071 MACHEMEHL, J. L. 1972 (Jul). "Dredging, Blasting, Battle Hurricane," World Dredging and Marine Construction, Vol 8, No. 8, pp 25-26.

Core Banks is one of several narrow sand barrier islands separating the Atlantic Ocean from Core Sound, North Carolina. Drum Inlet is a small natural inlet used by small craft in the area; its location is about 23 miles northeast of Cape Lookout. Over several hundred years, the inlet has opened, closed, and moved several times due to natural forces such as hurricanes and flood flows in the Neuse River estuary. Between 1933 and 1970, the inlet migrated 2,400 feet to the southwest as a result of five major hurricanes. Maintenance dredging from 1940 to 1953 kept it open, with dredged material being deposited behind dikes on the northeast side. In 1971, the Wilmington District of the U. S. Army Corps of Engineers cooperated with JERAC Corporation to use explosives to create a pilot channel, followed by suction sidecast dredging, for improving navigation safety, water circulation, and enhancement of local fish habitat. The segment removed with 26 tons of explosives was 385 feet long, creating a pilot channel 6 feet deep and 80 feet wide. The explosives were set in two parallel rows of 22 each, with 4 charges set in the inlet. Follow-up dredging was done by the Corps dredge "Merritt," which disposed of the material in the littoral zone.

1072 MACKLEY, F. R. 1973 (Aug). "Development and Use of Air Cushion Equipment Including Amphibious Platforms," Proceedings, Institution of Civil Engineers, Part 1, Vol 54, pp 413-424.

The air cushion vehicle has been adapted for a variety of civil engineering projects. It can move both heavy and awkward loads (either self-propelled or towed), and can be used as an amphibious work platform. Several types of air cushion vehicles are described. Hover trailers are not self-propelled and were developed for land use, primarily to transport large pipes across swampy areas or those of poor load bearing terrain. Capacities ranged at first from 7 to 20 tons, but connecting several can move larger items, even 500-ton oil storage tanks. The concept for an amphibious air cushion platform developed in 1970 in North Wales where a sea outfall project was beset by shallow water, heavy seas, high tides, and lack of a close port for safety. The first hover platform suction dredger was built in 1972 on pontoons modified with skirts to hold the air cushion. It can accommodate 100 tons of its own weight, a 12-inch dredge, and auxiliary equipment, and it is self-propelled by two 280 horsepower Volvo diesel engines producing 97,000 cubic feet per minute of air from two centrifugal fans. The dredger needs no special launch area, operates in all conditions regardless of tide or ground surface, and is highly maneuverable. Flat platforms using air cushions would provide a quick and economical means (a "miniport") for unloading large cargo payloads where port facilities are too expensive, such as in developing countries. It is not unreasonable to envision air cushion transport of up to 20,000 tons in the future.

1073 MAKAY, E. 1971 (May). "Design of Fluid Movers: Centrifugal Pump Expertise for the Nonexpert," Machine Design, pp 140-144.

A total of ten charts (sets of curves) and a brief explanation are presented to assist with understanding design methods for centrifugal pumps. This concept of custom pump design may be either mandatory for a specific application or may be used simply as an economical alternative for an integrated fluid-moving system. Basic dimensions selected first include pump head, flow, pump speed, approximate impeller outside diameter, impeller inlet (eye) diameter, impeller width, and number of impeller vanes. Secondary calculations include a refined impeller outside diameter, Euler head, hydraulic efficiency, and slip factor. The final step is to make calculations regarding the diffuser (or volute) throat area, because it is one geometric parameter most responsible for hydraulic instabilities. A chart is provided which shows experimentally verified values of impeller exit to diffuser throat area ratio. When the area ratio is incorrect, the results are lowered efficiency, hydraulic instability, increased noise level, and mechanical vibration. Several formulas and examples of calculations are presented to accompany the design charts.

1074 MALSTROM, E., RICHARDS, H., and BOOTH, L. 1980 (May). "High Mineral Prices Create New Interest in Dredge Mining," World Dredging and Marine Construction, Vol 14, No. 5, pp 29-36.

Because of soaring prices worldwide for gold and other precious metals, renewed interest in placer deposits has developed. Every abandoned or unused mining dredge in North America has been moved or placed under option. Examples of renewed mining areas include Brazilian tin mines and gold mines in New Zealand, California, and Colombia. In the Yuba Consolidated Goldfields near Marysville, California, a joint venture will begin mining on a 410-acre tract in 1981. The company owns 10,000 acres of potential mining area; it is the world's largest placer mine. The gold mine dredges will have their bucket ladders extended so that mining depth can be increased from the present 110 feet to 150 feet. Gold reserves on the 410-acre tract have been confirmed to permit production of 20,000 ounces of gold per year for 7 years. Dredging projects for gold in New Guinea and Bolivia also are described. Bucket dredges are used on all placer deposits because they have the ability to collect material without dispersing the values, as a cutter suction dredge would do. This article concludes with a discussion of the precious metal exploration, testing, and mine management services offered by Consolidated Placer Dredging, Inc., of San Francisco, California. A Brazilian and English firm offer similar services.

1075 MANATT, R. R. 1971 (Nov). "Dredging for Flood Control," World Dredging and Marine Construction, Vol 7, No. 12, pp 26-28.

In the early 1930's, a momentous decision was made by General Harley B. Ferguson of the Corps of Engineers to dredge cutoffs (shortcuts between river meander loops) in the channel of the lower Mississippi River. This was done in the face of criticism from many sides,

but something needed to be done to reduce flooding such as occurred in 1929. The first hydraulic dredge contracted for the project was the "George W. Catt," a 27-inch, 3,500-horsepower steam dredge belonging to the Atlantic, Gulf and Pacific Company. Although it experienced difficulties early in the work, it finally began to build cutoffs. Over a period of 13 years, the "Catt" was awarded 14 of 21 channel straightening contracts from three Corps districts. During this time, it dredged over 147,808,000 cubic yards, more than removed in building the Houston Ship Channel, and two-thirds that required to open the Panama Canal. The cutoff dredging was quite successful. Flooding in 1937 was much less than in 1929, even though 1937 was a tremendous 2,200,000 cubic feet per second at Arkansas City (22 percent more than in 1929). The 1937 flood gage reading was 7 feet lower than in 1929, but it would have been 4 feet higher had much of the cutoff dredging not been completed. The entire channel straightening bottom was completed in 1945, and General Ferguson's decision was definitely justified.

1076 MANLEY, C. 1975 (Apr). "Mexico to Receive Hopper Dredge," World Dredging and Marine Construction, Vol 11, No. 5, p 14.

A brief description of Mexico's newest dredge, the "Presidente Guadalupe Victoria," is given. The vessel is the sixth of eight being built for Mexico by a French shipyard; it also is the largest. The vessel is a 3,000-cubic-meter, self-propelled hopper dredge costing $9.6 million (in U. S. dollars). The length of the dredge is 111 meters, with a beam of 17.4 meters, and a draft of 7 meters. The single diesel dredging motor is 1,810 horsepower, and the ship is propelled by twin 1,470-horsepower diesel engines. The other dredges being sent to Mexico include five hopper dredges, each with a 1,500-cubic-meter capacity, and two dredges of 500-cubic-meter capacities. When the acquisition program is complete in 1976, Mexico will have the largest and most modern dredging fleet in Latin America.

1077 MANN, M. S. 1953 (Feb). "For Help in Pump Selection, Here's How to Use System-Head Curves," Chemical Engineering, Vol 20, No. 2, pp 162-164.

A graphic analysis is presented for comparing system-head curves with pump performance curves. A system head curve represents the relationship between flow and hydraulic losses, and each system has its own characteristic curve and specific values. In superimposing the system-head curve over a head capacity curve of a candidate pump, the curve intersection defines the operating point of the pump. Typical examples of common pipe layouts are discussed, especially with regard to factors brought to light when the curves are superimposed. Hydraulic losses include pipe friction losses, fitting losses, entrance and exit losses, and losses due to sudden or gradual changes in pipe diameter. In low-head, high-capacity pump situations, it is imperative that all hydraulic losses be taken into account. However, when high static lift and/or high pipe friction losses (long lines) are involved, it usually is not necessary to account for losses other than pipe friction losses; other losses

become insignificant. All but two of the thirteen examples account only for pipe friction losses. Among the cases examined are: (1) no lift--all friction head, (2) mostly lift--little friction head, (3) negative lift--gravity head, (4) two different pipe sizes, (5) two different static lifts, (6) part of flow diverted, (7) effect of pump wear on capacity, (8) low-speed pump near shut-off, (9) variations in the system head, and (10) parallel or series operation.

1078 MAUDE, A. D. and WHITMORE, R. L. 1958 (Aug). "The Turbulent Flow of Suspensions in Tubes," Transactions, Institution of Chemical Engineers, Vol 36, pp 296-304.

Considerable amounts of experimental data are available about the turbulent flow of suspensions in pipes, but most of the data are from horizontal pipes or flumes where some stratification is inevitable. Where measurements in vertical pipes are reported, the static head usually has been much greater than the head due to friction losses so that results showed little of what was occurring in the body of the fluid. This article describes investigations into the mechanism of turbulent vertical flow using narrow tubes and aqueous suspensions of fine, graded emery powder, and discusses how this flow differs from that of a simple liquid. The apparatus is described in detail; three diameters of glass and stainless steel tube were used, and location of pressure tap holes eliminated end effects. The relationship between viscosity and volume concentration of the emery suspension was measured under "streamline-flow conditions" in a coaxial, rotating-cylinder viscometer. Sources of errors in measurements never exceeded ±2 percent. Curves of friction factor versus Reynolds number are presented. An equation relating concentration to viscosity of the suspension was found to be valid up to a volume concentration of about 20 percent. Between 20 and 27 percent, another k' constant had to be introduced to the equation; this approximation becomes poor above 29 percent and no theoretical relationship is derived for such suspensions.

1079 __________. 1958 (Dec). "A Generalized Theory of Sedimentation," British Journal of Applied Physics, Vol 9, pp 477-482.

Equations are derived to show the relationship between the concentration and sedimentation velocity of nonflocculated suspensions of particles. Many theoretical and empirical relations have been proposed, but they have suffered from numerous defects; in particular, they lacked generality. Considerable value would be gained if an equation could be derived to cover wide ranges of particle shapes, size ranges, and rates of fall; the derivations contained in this article attempt this. It is shown that the settling velocity (relative to that of a single particle in the suspension) is represented by a simple formula--(1-c) raised to the B power; where B is a function of particle shape, size distribution, and Reynolds number, and C is the volume of solid per unit volume of suspension. Influence of the size and shape of the containing vessel is negligible in most cases where the size is great in comparison to the volume of suspended particles. The expression derived is shown

to satisfy the experimental results of several other researchers. An empirical relationship between B and the Reynolds number is suggested.

1080 MCDOWELL, A. W. K. 1980 (May). "The Underwater Bucket Wheel Excavator--A Review of 15 Years of Ellicott Experience," World Dredging and Marine Construction, Vol 14, No. 5, pp 7-12.

The Ellicott "Dragon Wheel" bucket wheel excavator is now an energy efficient device for applications in mining relatively hard materials. Fifteen years of this company's development is traced, beginning in 1965. Initial tests at a sand plant in Baltimore were promising, but not satisfactory for marketing. Negative aspects of testing were that clay often lodged in the bucket throats, continual excavation was hard to control if proper distance from the bank was not maintained and, if spuds were not properly set, the dredge backed away from the cut. Modifications gave successfull uses for a mineral mine where the material consistency was like soft asphalt. In mining raw sodium sulphate salt in Saskatchewan, the Dragon Wheel easily produced finished salt while a cutter head dredge was able to produce such small quantities that it all dissolved in the 6,000-foot-long discharge pipe. When used for the first time in sandy (abrasive) materials, problems were encountered with the drive motor seal. Design was improved by adapting a standard rotary cutter reduction gear to the bucket wheel. Several other jobs are described which utilize Dragon Wheel bucket dredge units ranging in horsepower from 100 through 1,500. The invention and use of a "traveling spud" system to use in conjunction with the bucket wheel has greatly improved performance and production.

1081 MCMANUS, H. P. 1968 (Feb). "Introduction to Suction Dredging," Transactions, Institute of Marine Engineers, Vol 24, pp 1-8.

Since World War II, hydraulic suction dredges, especially trailing dredges, have become the most popular type for maintenance dredging, and most bucket dredges are only built now for special applications. A brief history of dredging is presented beginning with the mid-seventeenth century, horse-powered, trough and board "mud elevators." Ten types of dredges are briefly described, but the remaining details of dredging are confined to the side pipe trailing dredge. A classification system for dredged material is presented, ranging from clay particles (less than 0.002 mm) to cobles (60 to 200 mm). Hydraulic transport of material is defined as one of three forms: moving bed, saltation, and suspension; suspensions are further explained with respect to being homogeneous or heterogeneous. Head loss, drag coefficient, and particle size are discussed relative to hydraulic transport. Among the other major topics covered are dragheads, pumps, pump drives, hoppers, hoisting gear, sluice valves, general operation, and automation. Future trends in dredging are covered in a concluding section. The author believes that emphasis possibly will swing to mineral recovery at depths of up to 600 feet on the coastal shelf, especially after land deposits are worked out. Completely submerged, fully automated suction dredges seem to be an answer to overcoming the violent storms and allowing mineral work on the coastal shelves.

1082 MCMANUS, H. P. and IRVING, R. 1967 (Oct). "Reclamation Dredging and Instrumentation," Proceedings, Institution of Civil Engineers, pp 97-103.

Hydraulic reclamation dredges and the problems associated with their operation are discussed. The principle reasons for reclamation dredging are: (1) it is more economical to pump ashore than dump elsewhere, (2) the deposit area is being used as an industrial or other site in conjunction with port or channel improvement or as a project in its own right, and (3) the material is suitable for commercial on-shore exploitation. Several types of reclamation dredges exist, but the most common is the fixed or floating pumping station. Each dredge consists of a suction, pump, discharge, and driver for the pump; it is the matching of these components which poses the main design and operational problems. With mixed or uniform particles, if deposition in the discharge pipe is to be avoided, the peak rate of material feeding must be such that when the installed power is being absorbed, the velocity in the pipeline is capable of transporting the material. Thus, a controlled feed to the suction system is desirable. Aspects of suction system/dredge pumps, discharge systems, and automatiion are discussed relative to optimizing and improving hydraulic dredging. Currently available imstrumentation such as vacuum gauges, density meters, pressure gauges, and simple electronic computers can assist dredgemasters, but the simultaneous reading and comprehending these varying outputs is beyond the command of the normal operator. The implication is that the entire system should be automated, but the consequences of taking this step are enormous and improvements in instruments and reliability are still needed first.

1083 MCNAMARA, R. F. 1961. "Fundamentals of Solids Pipelining: Past, Present and Future of Solids Pipelining," Pipeline Industry, Vol 15, No. 6, pp 64-67.

This first of a three-part series contains a brief history of solids-carrying pipelines. The first records of hydraulic systems handling solids goes back to the gravel-water pumping used in the California gold fields in the 1850's. The first patent for solids transport in liquid dates to 1891, but no commercial use was ever made of the invention even though it contained all basic components. The first solids pipeline was put into actual use in 1914 when 50 tons of coal per hour was pumped 1,750 feet through an 8-inch cast iron line in England (between coal docks and a boiler plant). Many other more recent applications are noted, ranging from the 110-mile-long Ohio coal line to the 20 phosphate systems in the United States. In addition to moving coal and phosphate, limestone, borax, gilsonite, sulphur, wood pulp, milk, sand and gravel, rock salt, and food grains have been moved or considered for transport by pipeline. Lignite breaks up too easily and some foods are imparted strange tastes; therfore, some resources cannot be hydraulically piped. Three conditions must be met before a solid can be handled in a pipeline: (1) solids must not undergo any undesirable change, (2) the slurry should not exhibit wide variations in viscosity,

and (3) particle size must not be too large. Maximum particle size transportable is one of the difficult factors to determine because percentage of large particles in the slurry, particle shape, fluid velocities, and specific gravity difference of fluid and solid all influence the system.

1084 MCNAMARA, R. F. 1962 (Jan). "Fundamentals of Solids Pipelining: Designing Solids Pipeline Systems," Pipe Line Industry, Vol 16, No. 1, pp 50-53.

In this second part of a three-part series, design of solids-handling pipeline systems is considered. Such systems are complex because the usual hydraulic problems must be taken into account as well as those involving initial slurry preparation and later recovery of the solids. Types of slurries are described as homogeneous (colloidal) suspensions and mixtures of free-falling solids in an inert carrier. Colloidal suspensions can be of three types: pseudoplastic suspensions, dilatant suspensions, and Bingham plastic suspensions. Bingham plastics are common in industry (clay and limestone slurries). Stress must be added to the fluid before it will start flowing. Several types of calculations are reviewed for the colloidal, non-Newtonian fluids. Nonhomogeneous mixtures settle out, and of primary importance with these is to keep the velocity high enough so that turbulent flow occurs. The equation for pressure gradient in a pipeline carrying settleable mixtures is presented and reviewed. Minimum pressure gradient is discussed at length along with particle classification schemes. Some researchers have observed that the introduction of fine particles in a suspension of larger solids tends to reduce the expected pressure drop. The reason for this has yet to be established, but it means that using an average particle size in calculations is more reasonable than the use of the largest particle size.

1085 MELZER, L. 1962. "New Types of Suction and Bucket-Ladder Dredger," Czechoslovak Heavy Industry, Vol 10, pp 20-31.

Ten new or recent designs of suction type and bucket-ladder dredgers, all of which are part of the heavy industrial export machinery line from Czechoslovakia, are described in this article. Each dredger is classified according to dimensions and hourly or daily production. Operating method, spud equipment, dredging depth, material disposal method, pump machinery, and controls are discussed. The ability of each dredge to handle certain types of sediment is brought out. Several of the dredges have been fitted with automatic program controls to maintain preselected density ("saturation") of the dredged mixture; direction, width, and depth of the channel profile; and the length of the path. There would be no reason for automatic control unless it controls the course of operations better than the dredgemaster. With automation of the suction dredger, the following traits were observed: (1) increased limit and reduced fluctuation of mixture concentration; (2) higher attainable output; (3) more precise maintenance of the depth, width, and direction; (4) better protection of mechanisms against overloading;

(5) higher utilization of mechanisms; and (6) reduction of fatiguing or harmful work to a minimum. Numerous equipment photographs accompany the article.

1086 MELZER, L. 1968. "SB 2500 Suction Dredger," Czechoslovak Heavy Industry, Vol 1, pp 36-44.

This article describes one of the largest of a new line of dredges built in Czechoslovakia. The dredge designation is SB 2500; it is a suction-type dredge using a 10-meter-wide- "dust-pan"-type head, and it is self-propelled by 1,675 horsepower. The dredge's production per hour can be as much as 2,500 cubic meters with a relatively short delivery pipe (400 to 600 meters). While in operation, the dredge digs a series of parallel ditches (at a maximum depth of 14.0 meters) and is anchored by means of five anchors. The width of each ditch is 11 meters and can be up to 400 meters long. Without having to transfer the lateral service anchors, up to 18 parallel operations can be made. Control of the vessel is concentrated in the wheelhouse, where only two or three men are needed to operate the entire system. Automated mechanization and monitoring are used as much as possible, resulting in exceptional output. Specification charts, drawings, photographs, and textural descriptions of machinery, electrical equipment, dredging equipment, piping, and controls are given.

1087 MICHIYOSKI, I. ET AL. 1966. "Flow of Slurry Through a Circular Tube; Part 2, Friction Factor for Tubes," International Chemical Engineering, Vol 6, No. 2, pp 382-388.

This is the second part of an analysis of laminar flow of a Bingham plastic fluid (2-micron diameter alumina powder in water) in a circular tube. Variations in the Bingham viscosity are examined along with the yield value of shear stress with temperature differences and volume fraction of solids in the slurry. Using experimental data, friction factors for laminar and turbulent flow in circular tubes are evaluated. Results are summarized by representing friction factors as functions of the Reynolds and Hedstrom numbers. Among the major conclusions are: (1) the relation between relative viscosity and volume fraction of solids nearly obeys Taylor's equation when volume fraction is less than 10 percent, but for higher solids content the relation is better represented by Eirich's equation; (2) the yield value of shear stress increased in proportion to about the third power of the volume fraction; (3) variation of Bingham viscosity with temperature can be expressed by an equation similar to Eyring's equation; (4) in laminar flow, observed friction factors agreed well with theory.

1088 ________. 1966. "Flow of Slurry Through Circular Tubes; Part 3, Velocity Distribution in Turbulent Flow," International Chemical Engineering, Vol 6, No. 3, pp 534-539.

This third part in a series concerning slurry flow through circular tubes gives results of research on the turbulent velocity distribution and eddy viscosity of Bingham fluids. Velocity distribution is

examined theoretically by the use of friction factors derived in Part 2 of the series, and is compared with experiments. No previous research data (theoretical or experimental) were found concerning velocity distribution of Bingham fluids. The apparatus used is described in Part 2 of the series. Conclusions drawn from experiments reveal that points for velocity distribution lie about in the middle between theoretical lines drawn by the logarithmic and power velocity distribution laws. Eddy kinematic viscosity increased with an increase in Reynolds number when the Hedstrom Number was held constant, and with an increase in the Hedstrom number when the Reynolds number was held constant. These rules hold within certain ranges of Reynolds and Hedstrom numbers; these ranges are provided. Within a certain range for each number, both the turbulent velocity distribution and the eddy kinematic viscosity coincide with those of Newtonian fluids.

1089 MILNE, D. C. 1964 (Feb). "Dredging at the Port of Manchester," Proceedings, Institute of Civil Engineers, pp 17-46.

A detailed description is provided for dredging work at the Port of Manchester (River Mersey) over several decades. Some infcrmation dates as early as 1930, but most relates to the post-World War II years up to 1963. Problems with management, dredged material type, equipment, disposal procedures, flooding, and cost control are discussed for separate locations of work including the ship canal, approach channel, and Queen Elizabeth II dock. The final section covers hopper loads and barges. Total quantity dredged per year averaged 6.75 million cubic yards, and involved a variety of dredging plants, but primarily bucket dredgers. Suction dredgers are used in the approach channel. Model experiments were used in some situations to optimize corrective measures for appropriate dredging or to calculate ways to prevent future problems. Efficient operation of a dredging fleet depends to a large extent on careful organization designed to guide dredging units to maintain uniformly high outputs. The approach taken at the Port of Manchester in regard to efficient operations is described. Working costs (both labor and material costs) under various conditions and with several equipment types are compared. Dredging in the approach channel is entirely different than dredging in the ship canal; these differences are discussed along with a remarkable improvement that has followed the introduction of a new dredging technique; use of trailing suction hopper dredges.

1090 MISER, J. W., STEWART, W. L., and WHITNEY, W. J. 1956 (Oct). "Analysis of Turbomachine Viscous Losses Affected by Changes in Blade Geometry," Memorandum No. RM E56F21, National Advisory Committee for Aeronautics.

A detailed analysis is presented concerning changes in blade geometry and how these affect viscous losses in axial-flow turbomachines. Principal aerodynamic losses in turbomachines are attributed to the development of a boundary layer on the surface of the blades and the inner and outer walls. The variables affected by blade geometry changes that are considered in this study are blade number, solidity, aspect ratio,

pattern which gives good results. However, to save costs on such a large project, it was found that extending the drilling spacing by 1.4 feet and the depth by 3 feet, the same results could be achieved using fewer holes and more explosive per hole and save about $1 million per mile. A new dipper dredge, the U. S. "Rialto M. Christensen" is removing the fragmented rock ("muck") resulting from the blasting.

1116 ORTON, J. B. 1973 (Sep). "Decca Provides Aids to Dredging," World Dredging and Marine Construction, Vol 9, No. 11, pp 41-42.

Since World War II, the Decca organization has been developing navigational aids and providing services for the control of dredging operations. Within the past 15 years, Decca equipment and personnel have been involved with over 400 projects involving electronic positioning; 61 of those have been dredging projects. More accurate positioning has been required since the mid-1950's, with the advent of deep, offshore approach channels being needed for deep-draft vessels. This article describes the Trisponder system (a microwave system limited to line-of-sight) and the Hi-Fix 6 system (a radio-signal system especially useful for large or awkwardly shaped dredging areas). The advantages of each system and of peripheral equipment such as chart plotters, left/right indicators, and echo sounders are expounded. The use of attached track plotters is emphasized, noting that any track plotter is only as accurate as the basic positioning system. With careful shore station siting, a pattern of signal transmissions can be placed along the axis of the dredging channel so that much better control of channel width is possible. The Decca systems are built on the "building block" scheme so that other compatible modules can be added. The new development of "dynamic positioning" is discussed briefly.

1117 OYAMA, Y. and ITO, S. 1954 (Dec). "Studies on the Transport of Slurry in Circular Pipe: The Transition Region Between Laminar and Turbulent Flow," Journal, Scientific Research Institute, Vol 48, No. 1369, pp 227-244.

For the design of pumping equipment and pipelines for transport of suspensions, there is a significant need to have a general rule concerning the "transition region" in which flow is changing from laminar to turbulent. Likewise, the characteristics of pressure drop due to friction in the turbulent flow state require further study. This article reviews past works and presents additional experimental data on evaluating the transition region and concomitant pressure drop for non-Newtonian fluids, in particular. Bingham plastics (which exhibit plug flow). Five results are summarized after discussion of previously derived equations and graphical data. These results present a formula by which Reynolds number should be expressed for Bingham fluid. If such a number is used, correlation of friction factor versus Reynolds number becomes a unique one available for either the case of Newtonian or Bingham fluid for a given set of flow conditions. This is confirmed by a flow test of clay suspensions in an experimental line (comparisons made with water). The location of the transition region is experimentally

1968 that it would undertake to standardize soil definitions for dredging applications after nearly a century without a consistent classification. The manner in which the PIANC Commission established such a system and the reasons for such classification are presented. The system itself is given in tabular form. Visual, manual, and laboratory observations of soils are discussed relative to the standardized system. The system includes the following: (1) boulders (larger than 200 mm); (2) cobbles (60 to 200 mm); fine medium, and coarse gravels (2 to 60 mm); fine, medium, and coarse sand (0.06 to 2 mm); fine, medium, and coarse silt (0.002 to 0.06 mm); clay (below 0.002 mm); and peats and organic soil (size range not applicable, but generally identified by strong organic smell and presence of fibrous or woody material).

1114 OOSTERBAAN, N. "The Cutter Suction "Vlaanderen XI" Working Successfully in Belgium and Scotland," Ports and Dredging, Vol 25, pp 3-5.

IHC Holland was requested to construct a dredger which had some rather unique requirements: two pumps (each driven by 1240 horsepower), ability to be dismantled into sections having a maximum weight of 20 tons, transportability by road in Belgium and the Belgian Congo, and towable at sea. The vessel was successfully built in 14 months. It had a length of 142 feet, a beam of 39 feet, a draft of 9 feet, and a dredging depth of 52 feet. It was capable of pumping dredged sandy materials up to 16,500 feet. After being built, the ship first was transported dismantled on barges to Ghent, then towed on heavy trucks to the assembly site. A travelling crane and prepoured concrete foundations permitted reassembly. A dike around the dredger was filled with sea water and the dredger floated. In 18 months the "Vlaanderen XI" delivered 1,600,000 cubic yards of sand about 3 miles to restore beaches at Knocke which had been seriously eroded. After this successful operation, the vessel was transported to Scotland in the dismantled condition and reassembled for removing top soils from an open cast coal mine.

1115 ORIARD, L. L. 1980 (Jun). "Drilling, Blasting, and Dredging Techniques in the Panama Canal," World Dredging and Marine Construction, Vol 16, No. 6, pp 24-26.

A test program is described which was initiated in 1977 to study drilling, blasting, and dredging procedures required to deepen the Panama Canal by an average of 9 feet along 8.5 miles through the Gaillard Cut between Pedro Miguel and Gamboa. Several pieces of equipment owned by the Panama Canal Company are performing the work. The drill barge "Thor" has four drill towers, each 90 feet high, that move along rails on one side. Fish-tail bits are used to drill a 4.5-inch hole, which is then reamed to 5.125 inches. Positioning of the drill barge generally and for refined, accurate charge placement is described, as are the placement of charges in the holes and the means of detonation. Millisecond delay electric blasting caps are used to initiate detonation in bundles of Primacord detonating line. Through previous experience, the Panama Canal Company had established a basic drilling and blasting

should not be computer programmers; therefore, the data entry system is based on operator "prompting." The system's basic program is built in, so that if a complete power failure occurs, the basic program remains without having to reprogram. The system consists of two shore-based reference stations, a range console, and a receiver/transmitter with antenna. The processor accepts range-range data and converts it to Universal Transverse Mercator (UTM), state plane, or geodetic coordinates. By placing shore stations at presurveyed locations, survey boat or dredge positions can be determined and displayed in 1 second with an accuracy of ±1 meter. The products are readouts of preplot charts showing where to dredge, postdredge plots, and proof of material removed. Minimal operating time is used. A dredge operator can steer the dredge down desired lines with enough precision to preclude overdredging. Other standard or easily attached features include depth sounder input, sample internal entry, system calibration, event mark entry, independent chart plotter orientation, atmospheric and grid correction, tide table entry, and tape file numbering, among others. The U. S. Army Corps of Engineers has 60 such systems (250 reference station) installed or ordered. Free training schools are given annually.

1112 OEBIUS, H. U. 1975 (Aug). "Research Institute's Role in Dredging Business Revealed," World Dredging and Marine Construction, Vol 11, No. 9, pp 31-33.

The advantages of having dredging problems considered by research institutes of widely varied disciplines, but with professional and concerned individuals, are presented. Both "customers" and "executers" are becoming aware of greater technical, ecological, economic, and public related responsibilities in dredging. Planners, concerned citizens, and contractors should meet at one table and determine the most equitable alternative. They should also rely on experts, and that is where research institutes should enter the picture. The institute experts encompass oceanographical, geological, and biological disciplines, and at the same time are concerned with optimization of the problem solving process. For all groups, generally, the economic "commandment" has top priority. The most appropriate scientific institutes are those which combine many disciplines under one roof. Three examples of the use of institutes are given. In one case, a study of draghead efficiency yielded a 300 percent increase in overall dredge system efficiency. A subsequent program on improving hoisting systems is expected to boost total dredge efficiency by at least another 100 percent.

1113 OOSTERBAAN, N. 1973. "On the PIANC Classification of Soils to be Dredged," Terra et Aqua, No. 5, pp 29-32.

For dredging purposes, the nature of the soil is the most important factor to be considered because it affects the manner in which an operation is carried out and also the equipment chosen for the work. Soil is here defined in the engineering sense as any naturally occurring loose or soft deposit forming part of the earth's crust. The Permanent International Association of Navigation Congresses (PIANC) decided in

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1109 OBIAKOR, E. K. 1965 (Oct). "Transportation of Coal Slurries in Pipelines," Colliery Guardian, Vol 211, No. 5450, pp 432-436.

The rheology and mechanics of slurry flow are reviewed with particular emphasis on experimental approaches taken by various researchers. In Britain, all coal transport is by rail and/or road transport, in contrast to other countries where several coal slurry lines are in operation. This is surprising because water availability is not a limiting factor. One study has shown that coal fines with 30 to 40 percent water content could be fed directly to a boiler for burning. Viscosity, flow equations, and the phenomenon of "plug flow" are discussed in detail. An equation is derived which shows how the velocity of a slurry depends on pipe diameter, plastic viscosity, pressure difference per unit length of slurry, and ratio of yield stress to shear stress at the pipe wall. It appears that the economic advantage which is claimed for operating pipelines of slurries in the "plug flow" region results from using relatively low velocities. Head losses, settling in pipelines, and pumping characteristics are further considered. The conclusion offered is that further work needs to be done before the feasibility of pipeline transport of British coal slurries can be convincingly established.

1110 O'BRIEN, M. P. 1933. "Review of the Theory of Turbulent Flow and Its Relation to Sediment Transportation," Transactions, American Geophysical Union, pp 487-491.

The theory of turbulent flow (both in open channels and pipes) as developed by Reynolds, Prandtl, Van Karman, and other early researchers is reviewed, especially with regard to distribution of suspended particles. Discussions center on shearing force and viscosity, shearing force and momentum transfer, and distribution of suspended materials. Conclusions note the following: (1) the theory of turbulent flow could be checked by simultaneous measurements of sediment distribution and average velocity at each depth; (2) a practical application of the theory, if it is verified experimentally, lies in the computation of total volume of sediment carried in suspension; (3) using derived equations, a knowledge of the distribution of sediment could be obtained from a single measurement of the "silt" content and a curve of the distribution of velocity; and (4) the theory of turbulent flow probably is not valid in the region where sediment is picked up from the bottom and placed in suspension.

1111 O'DONNELL, W. T. 1980 (Mar). "Advancements in Electronic Positioning and Volume Computation for the Hydrographic Survey and Dredging Industries," World Dredging and Marine Construction, Vol 16, No. 3, pp 19-21.

Motorola's electronic position determining system for dredging and hydrographic surveys, the Mini-Ranger III, is described. The original premise of developing the system is that average dredge employees

orifice plate (ranging from 23.33 mm to 66.60 mm in diameter). Pipe diameters used were 104.10 and 105.26 mm. Straightening vanes were employed 25 diameters upstream from the orifice to produce desirable metering conditions. Formation and size of cavitation were visible through a clear pipe segment (15 cm long), and were photographed at a flash duration of 1/100,000 second. Discussion is presented on the manner of cavitation occurrence, variations of discharge coefficient, and a means to counter noise and vibration. Conclusions indicate that: (1) the discharge coefficient K is not influenced beyond the standard allowable tolerances to a minimum cavitation number of 0.2; (2) the incipient cavitation number is about 2.5 and is independent of the orifice - pipe diameter ratio for the size ranges tested and for the test velocity and static pressure; and (3) the method of "air inhalation" may be employed to suppress vibration and noise caused by cavitation. Follow-up discussion showed that the discharge coefficient is not influenced to a minimum cavitation number of 0.001.

1106 NEMINSKII, M. L., FROLOV, P. I., and GALLIULIN, A. A. 1974 (Nov). "Selection of the Optimum Type of Deep Suction Dredge," Gidrotekhnicheskoe Stroitel'stvo, No. 11, pp 27-29.

Three types of suction dredges were constructed and tested for usefulness and economy in dredging sand and gravel deposits from 15 to 30 m below the surface. One type has immersible dredging pumps and can dredge to a depth of 45 m. The second has an air-lift system and can dredge to a depth of 30 m. The third type has an ejector suction system and also can dredge to 30 m. All three were tested in similar quarry conditions during 1971. The ejector dredge produced the highest slurry consistency and gravel output per hour. The air-lift dredge has to work in an almost vertical position; that is a great disadvantage and often means the suction tip is driven into the soil and obstructed. For the ejector suction dredge, embedding the suction end in the soil leads to an increase of consistency and output. The most effective machine is the ejector suction dredge, producing at a cost of 0.29 rubles per cubic meter. Cost per cubic meter for the air-lift suction dredge was 0.42 rubles, while the cost for the immersible pump dredge was 2.45 rubles per cubic meter.

1107 NISHI, K. 1970 (Sep). "Suction Booster Pump of Pumping Dredger," World Dredging and Marine Construction, Vol 6, No. 11, pp 30-33.

With dredging depths tending to increase to 20 or 30 meters in Japan, one company has installed an axial flow booster pump on the ladder to prevent negative pressure on the main pump from going up and resulting in cavitation. Specifications of the booster pump are shown. The booster is protected from overload during quick shutdown. Vanes of the impeller are made strong enough to withstand impacts of rocks. The motor is of the caged type and is totally sealed for underwater operation. It also has oil-immersed construction and forced lubrication with oil pressure higher than outside water pressure. In tests with mixtures of 30 percent silt and 70 percent sand, dredging efficiency was 30 percent higher than when no booster pump was used. Cavitation, noise, vibration, and impeller pitting were reduced. Efficiency is most noticeable when sand carrying (pumping) distance is relatively short and dredging depth is greater. When sand carrying distance is 5,000 to 6,000 meters, use of the booster increased dredging efficiency less than 3 percent. Problems remaining to be solved include improving dredging where obstacles exist, adopting longer wearing parts, and making pump speed or vane angle adjustable for proper use of the main pump.

1108 NUMACHI, F., YAMABE, M., and OBA, R. 1960 (Mar). "Cavitation Effect on the Discharge Coefficient of the Sharp-Edged Orifice Plate," Journal, Basic Engineering, pp 1-11.

It is often desirable to use sharp-edged orifice plates for water flow measurement; however, there is concern that when cavitation is present, the discharge coefficient may be altered, particularly in regard to small pipe sizes and relatively high velocities. This article presents experimental results of testing of five difference diameters of

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1104 NARDI, J. 1959 (Jul). "Pumping Solids Through a Pipeline," Chemical Engineering, Vol 66, No. 15, pp 119-122.

A review is presented on the history of pumping solids through pipelines. Many applications of the process from 1914 through the 1950's are given. Earliest records, patent applications and claims, and the first commercial solids pipeline are discussed. Many pipelines proposed for transporting solids have been technically feasible, but were not sufficiently attractive economically to warrant the financial risk. In some cases, the difference in pipeline transport cost and cost using another mode was negligible. In the last few years, numerous slurry pipelines have been proposed, ranging from 30 to over 600 miles in length. While each of these has different and difficult engineering problems, there is always less doubt about technical feasibility than economic success. Preparation of solids for pumping as a slurry, and subsequent dewatering and drying, usually costs more and presents more difficult technical problems than the actual pumping or building of the pipeline. Pipelines are more economical than other modes when the following factors are involved: large quantities, many years of useful life, high annual load factor, and relatively long distances. Two advantages of pipelines over rail and truck transport are: a smaller proportion of operating cost in labor and materials, and the cost of returning empty containers is eliminated. Partial product processing in transit may be a key to a new upsurge in use of pipeline transport.

1105 NASH, D. 1980 (Mar). "Tidal Data Telemetry System Provides Continuous Depth Information," World Dredging and Marine Construction, Vol 16, No. 3, pp 11-13.

A new tide gauge and telemetry system known as the Marinav Tidal Data Telemetry system provides dredge operators with accurate depth information at 5-minute intervals. The system has a depth sensor (which corrects for barometric differences and averages data to account for wave-induced depth changes), a transmitter/processor unit, and a receiver/display unit. The overall accuracy is ±5 cm at depths up to 60 m. The gauge electronics unit can be installed on a pier or in a moored buoy. The processing unit converts pressure data to absolute water depth, after corrections. The transmitter/processor unit is battery operated, and battery life usually exceeds 30 days. Data received in the wheelhouse-mounted receiver unit is shown on a high visibility liquid crystal display. An optional output for strip chart recorder can provide a continual analog record. Maintenance can be done in the field; trouble-shooting to the circuit board level is possible with minimal understanding of the system's operations. Use of low power, integrated circuits reduces internal temperatures and part counts and results in good overall reliability.

capabilities to be able to handle a wide range of operating conditions. Principal physical characteristics and design features are described. All three were designed for damage stability. The largest is 409 feet long, 78 feet wide, with a design (loaded) draft of 29.5 feet. Hopper volume is 8,400 cubic yards, and it can dredge to 80 feet. It carries a crew of 40 in air conditioned comfort. The middle size is 350 feet long, has a draft of 27 feet (loaded), can dredge to 80 feet and has a hopper capacity of 6,000 cubic yards. It carries a crew of 38. Both the large and middle size dredge have two dragarms and dredge pumps. The smallest vessel is 200 feet long, 58 feet wide, with a draft (loaded) of 12 feet. It can dredge to 80 feet, and has a hopper capacity of 825 cubic yards. It carries a crew of 28. The house, superstructure, working environment, propulsion system, steering, dredging system, and automatic equipment are described for all three classes. A special waste beat recovery system is being installed on the middle size class. These new dredges will form the nucleus of a modern fleet that will be operated at high technological standards; they will continue to development of more effective hopper dredging operations.

1101 MUHLHAUS, J. O. H. 1960 (Oct). "Pumping Liquids Containing Solids," Engineering, Vol 190, p 562.

Problems encountered in pumping liquids containing solids are discussed in relation to pump wear and pump type selection. Centrifugal pumps are especially endangered because pump wear increases in proportion to the square of the velocity of the liquid containing abrasive constituents. Rubber bonding on parts has increased wear life, but this is an expensive method except where great volumes of liquids must be handled. Two main types of pneumatic pump can alleviate many of the wear problems: the air-lift pump and the direct displacement (two-chamber) type. The airlift requires 4 or 5 cubic feet of air at atmospheric pressure to lift 1 cubic foot of water against heads of 150 feet or more. This is not very efficient, but has given excellent service in dewatering mine shafts. Two two-chamber system results in a more even flow, and where the pulsating delivery is no disadvantage, this type of pump is recommended for simplicity, weight savings, and cost savings. A description of the operations (and a diagram) is provided for the Holman single-chamber sludge pump assembly.

1102 MUNCH, R. H. 1952 (Jun). "Instrumentation: Slurry Flow Control Requires Special Care in Selection of Automatic Control Valves and System Design," Industrial and Engineering Chemistry, Vol 44, No. 6, pp 73a-76A.

A new type of valve for automatic control of slurry flows is described. It is known as the "Ratogate" flow control valve, and can be used for any low pressure automatic control application. It prevents settling by agitation and is designed so that there are no crevices in the outlet in which solids can lodge. The inlet is located at the bottom of the valve so that material must flow over a gate to get to the valve opening. The gate has no top and bottom or side guiding surfaces to create excessive friction or to allow places for solids to wedge. A sight glass is provided in the top of the inlet chamber to permit visual observation. Two tapped openings are attached for connection to water lines for flushing. All sizes of this valve are equipped with pneumatic cylinders and positioners rather than with diaphragm type motors. Manual operation is not possible; therefore, if it is essential that flow be maintained at all times, a bypass should be installed. The major advantage is to throttle at low flow rates so that it has a range of operation of 13 to 1, in contrast to other slurry valves with a range of about 8 to 1. The design minimizes buildup of solids around working parts.

1103 MURDEN, W. R., JR. and MAURIELLO, L. J. 1980 (Oct). "Hopper Dredge Design Considerations," Proceedings, World Dredging Conference, WODCON IX, pp 149-173.

Three new classes of hopper dredge being built for the U. S. Army Corps of Engineers are described. These new dredges are part of the "minimum Federal fleet" required by Public Law 95-269 to meet all national defense and emergency needs. The vessels have a variety of

The central coastal area of Brazil will soon have a new port facility built specifically for handling pelletized iron ore, which will arrive via a 403-km slurry pipeline from Brazil's "iron ore quadrangle." Initial production will be 5 million metric tons annually, but the 20-inch line can handle 12 million tons per year. The port is being built in an area with 20-m-deep water close to shore. A rockfill causeway will extend out 840 m with a 365-m section parallel to shore. A steel construction pier also will be built. Ships will have access to the pier through a 1,400-m channel dredged to 18 m and a berthing area dredged to 19 m. Initially, 150,000 deadweight ton carriers can be handled. Dredging is being completed by a hopper dredge built by IHC, the "Wado." The dredge was built in 1972, and has a capacity of 6,300 cubic meters. It is powered by twin 5,200-horsepower diesel engines, which provide ship propulsion and pumping power. Material is being deposited offshore at a distance of 5 km or more. Bow thrusters assist maneuverability. The "Wado" can dredge to 30 m. One dredging cycle requires about 2 hours. Dredging commenced on August 9 to remove 2.4 million cubic meters of material. By December 15, dredging was complete in the pier area to permit breakwater construction. Most material was sandy, with some clay. "Canga," a loosely cemented iron formation required blasting before removal of 20,000 cubic meters. Dredging was completed in April 1976.

1100 MUELLER, N. H. G. 1964 (May). "Water Jet Pump," Journal, Hydraulics Division, ASCE, pp 83-113.

This article considers applications of water jet pumps and describes experiments performed to determine the optimum dimensions of the water jet pump so that the best efficiency may be obtained. The water jet pump's action involves the transfer or energy from a high velocity jet to one of a low velocity. Major applications at present in engineering include deep well pumping, booster pumping in pipe networks, dredging (to avoid passing the materials through a centrifugal pump), tailwater supressors in power generation, and as priming devices. Elements of the water jet pump are described in some detail, along with "ideal" and analytical efficiencies. Losses encountered include friction loss in the driving line, driving nozzle losses, suction nozzle losses, bend loss in the suction line, friction loss in the mixing chamber, and diffuser loss. Various dimensions of jetpumps were changed in experimental studies; these dimensions involved different driving nozzle patterns, profiles of mixing chamber entrance, diffuser angles, and driving nozzle diameters. Driving nozzle distance and mixing chamber length were varied while mixing chamber diameter was kept constant. In order to maximize efficiency and performance, driving and suction nozzles should be designed so that their velocity coefficients have values of 0.95 or more. Noncorrosive materials should be used. Careful selection of dimensions will guard against cavitation. Recommendations are made so that units can operate at efficiencies in the vicinity of 37 percent and outside the region of cavitation.

A broad range of topics related to dredging are covered in this overview by the Chief of Engineers, U. S. Army Corps of Engineers. The Corps, just as much as the dredging industry, has been obliged to accommodate the environmental impact statement process. Ultimately, it has been proven that the great majority of dredged material is perfectly all right (unpolluted) and a national asset that should be put to good use. The small but growing base of the American hopper dredge business is now beginning to be as competitive as the pipeline dredgers. Philosophy of the dredging industry versus Corps dredging is discussed with respect to the Industry Capability Program. In the most recent year, of 22 dredging jobs put out for bids (against the Corps), industry won 12 of them. Some people were unhappy, but at least both sides learned how to work together. The Corps will retain a minimum dredge fleet to meet effects of natural emergencies such as the flood of 1972 and 1973, or national emergencies such as Vietnam. Several forces are at work on a national level which will affect our ports, waterways, industry, and particularly, the water industry. These include the National Waterways Study, the Inland Waterways Systems Analysis, and the Waterways Repair Program. Several Washington, D. C., policies are reviewed; the major one is how the Federal role should be defined in local water resource development. Cost sharing is a big issue. Regulation is the alternative to President Carter's Conservation ethic.

1098 MORRISON, J. 1972 (Mar). "Sub Sea Oil Completes Trials on New Submarine Work Vessel," Offshore, Vol 32, No. 3, pp 81-87.

A new vessel which operates on the sea bottom, with a floating support ship, has been developed for submarine pipeline trenching or mining. It is operated in a dry cabin and can be ballasted to weigh from zero to 50 tons on the seafloor. In a single pass, trenches up to 8 feet deep and 15 feet wide can be cut at forward speeds of about 425 feet per hour, depending on the nature of the seabed. By cutting a parallel trench, it can be used for backfilling. Movement is by winching along cables set with anchors, and it can proceed forward or backward. The machine is transportable in modules, the heaviest of which weighs 35 tons. Maximum depth of work thus far is about 100 feet, but it can work at 200 feet in the present configuration. It is essentially a submersible cutter dredge that is maintained on a projected course by marker posts and guide cables. A built-in guidance system gives straight-line accuracy. The cutterhead is on a swing arm that can move horizontally or vertically by hydraulic actuators. Maximum horizontal swing is 30 degrees to each side. Depth of cut can be from 0 to 8.25 feet. The discharge pump is connected to two pipes set vertically at 45-degree angles. Discharged material falls freely to the bottom from 32 feet above the bottom. For mining, a single pump can discharge to shore or a surface vessel. Daily average cost, including crew and support equipment, ranges between $2,000 and $3,000. Another machine which does an excellent job of pipeline burying also is described.

1099 MOUSLEY, I. M. and CUNNINGHAM, R. E. 1976 (Jul). "Major Iron Ore Port Dredged in Brazil," World Dredging and Marine Construction, Vol 12, No. 8, pp 24-27.

1095 MOON, F. B. 1969 (Jun). "The McFarland, 2-1/2 Years After," Citation No. 70-07430.

A relatively new dredge built for the U. S. Army Corps of Engineers, the "McFarland," has performed excellently since being put into service. The vessel can perform conventional hopper dredging, side-cast dredging (using a 222-foot all aluminum boom), or pump-ashore work where bottom dumping is not feasible. It is 300 feet long, has a 72-foot beam, and a maximum loaded draft of 23 feet. Maximum dredging depth is 55 feet using a pair of dredges driven by 2,800 horsepower per pump. A full description and photographs are provided. Thus far it has performed mostly hopper dredging and dumping, with several months of side-cast dredging. The "McFarland" has dredged about 26.5 million cubic yards at a total cost (depreciation, surveys, overhead, fuel, labor, repairs, etc.) of under $6 million, or about $0.226 per cubic yard. While side-cast dredging, cost averaged only $0.0675 per cubic yard. Effective operating time was about 90 percent, and the majority of "de-bugging" alterations and repairs were performed while work continued. Problems encountered include vibration caused by propeller cavitation, leakage of stern tube lubricating oil, instrument failure due to vibration, and ventilating systems picking up diesel exhaust. All problems have been corrected. Virtually all of the innovative design mechanisms built into the ship and its dredging system worked remarkably well.

1096 MORELAND, C. 1963 (Jun). "Settling Velocities of Coal Particles," Canadian Journal of Chemical Engineering, Vol 41, No. 3, pp 108-110.

Settling velocities of solids are an important factor in pipeline transport of solid-liquid slurries. Although large amounts of well-correlated data exist for free-fall of spherical particles in liquids, little is known of the terminal and settling velocities of irregular shaped particles. The investigation reported here deals with settling velocities of coal particles falling by gravity through clear mineral oil of a known specific gravity and viscosity. Experimental conditions were controlled. Coal particle sizes ranged from 80 to 2,000 microns. For terminal velocities, about 20 measurements were taken from individual particles. Settling velocities were determined using five narrow size ranges between 80 and 325 microns diameter and porosities of 0.612 to 0.968. Terminal velocities are within 25 percent of predicted values for spheres, but cannot be related to them by applying a constant "shape factor" to the formula's "diameter" term. A formula is presented that well represents settling velocity. In order to accurately predict settling velocities of slurries of irregular particles, it is necessary first to assess their terminal velocity and choose a suitable value of n (a constant dependent on particle size and shape). As yet, no satisfactory correlation for shape exists.

1097 MORRIS, J. W. 1978 (Apr). "An Overview of Dredging in the U. S. A.," World Dredging and Marine Construction, Vol 14, No. 4, pp 26-30.

breakwater 30,000 feet long. To determine the most appropriate methods for efficiently accomodating expected shipping increases by the end of the century, a study was conducted by the Corps of Engineers and the Henry J. Kaiser Company. Nine alternatives were studied ranging from "no action" (maintaining the existing harbor and facilities) to completely modifying the lakefront and the Old River area, and to transship bulk materials. With changes, the Cuyahoga River and other areas would accommodate 1,000-foot-long vessels. Conceptual layouts and cost estimates were made. Tables provide data on costs and quantities of dredging needed for the alternatives. The highest benefit/cost ratio involves a conveyor system linking inland facilities with the port. Total dredging for this alternative is 42 million cubic yards (over a 50-year project life). This planned redevelopment program includes a balanced approach to blending engineering, economic, social, and environmental elements.

1093 MONTGOMERY, D. 1980 (Jul). "Dredges Battle Volcanis Silt in Columbia River," World Dredging and Marine Construction, Vol 16, No. 7, pp 19-21.

Portland has the largest export port on the U. S. West Coast, and 21,000 harbor related jobs are dependent on it. When Mount St. Helens erupted on May 18, deposition of shoals of hard, heavy, abrasive materials from the eruption began to block the Port. The Corps of Engineers responded immediately to allow ship traffic to flow. The suction dredge "Oregon" and three hopper dredges worked around the clock, 7 days a week to battle the material in the Columbia River channel. The dedication of the workers, problems encountered, and innovations and improvisations used in the massive cleanup are described in this article. The material was especially hard on equipment, eroding through pipes in a short time, crimping pipe ends, and keeping welders busy constantly. The entire activity reminded the author of a Naval operation, but the fighting is with cutterheads, dragheads, pumps, and pipelines.

1094 MOODY, L. F. 1944 (Nov). "Friction Factors for Pipe Flow," Transactions, American Society of Mechanical Engineers, Vol 66, pp 671-684.

A simplified graphical means of estimating friction factors is furnished to assist engineers in calculating head loss in clean, new pipes and in closed conduits running full with water. New data are not presented; however, works of several authors are reviewed, and data are used in new, more easily understandable charts. Data concerning the transition zone (of incomplete turbulence) between smooth and rough pipes need further refinement from more research. The plot of friction factor versus Reynolds number covers four zones: laminar flow (Reynolds number less than 2,000), the "critical" zone (Reynolds number from 2,000 to 4,000), the "transition" zone (Reynolds number from 4,000 to 10,500), and the "rough pipe" zone (Reynolds number above 10,500). A concluding section discusses application of pipe friction factors to open-channel flow.

Reynolds number, and trailing-edge blockage. Experiments show that viscous loss can be expressed as a function of three variables: blade height-to-spacing ratio, solidity, and a height Reynolds number. In the analysis it is determined that the blade number can be changed over a wide range from the optimum value with little effect on blade viscous loss. For solidity changes only, data show that solidity can be varied over a more limited range with negligible effect on blade viscous loss. Trailing edge blockage affects, to a large extent, the number of blades corresponding to the minimum total pressure loss. The number of blades chosen will decrease with an increase in trailing-edge thickness.

1091 MITYUSHIN, D. N. 1978 (Feb). "Unsteady Operating Regimes of Dredges," Gidrotekhnicheskoe Stroitel'stvo, No. 2, pp 35-37.

Operation of "spoil" pumping plants are based almost entirely on the theory of steady operating regimes with a constant consistency of the spoil. Unsteady, transient regimes occur with changes in density of suctioned spoil, and these have hardly been investigated. An analysis of transient system is presented as designed to further improve manual and, especially, automatic dredging control systems. Verbal and pictorial explanations of steps in the transient process are given. The usual pump and pipeline characteristics are examined, comparing steady state and transient regimes; graphical presentations depict behavior of vacuum, power, and head. Step functions of discharge, head, vacuum, and power also are shown as they respond to increase in spoil density for both the transient process and theory of steady regimes. The equation for the transient process is given as $(b_1 + b_2 l)l'' = b_3 l l' + b_4 l' + b_5 l + b_6$, where l is the distance from the start of the spoil pipeline along its axis to the moving boundary of the change in spoil density, l' is the velocity of spoil (first derivative), and l'' is acceleration of spoil (second derivative). The elements b_1 - b_6 are constants which depend on the length and diameter of the spoil pipeline, density of the pump, and characteristics of the pump and pipeline. Assumptions in deriving the equation are given. The purpose for solving the equation of transient process is to obtain the relation $l' = f(t)$, the velocity and discharge of the spoil as a function of time. Improving dredge control systems is discussed based on investigations of the transient process, and an example is given of design application.

1092 MONSON, R. and HENRY, J. 1976 (Feb). "Cleveland Harbor Modernization," World Dredging and Marine Construction, Vol 12, No. 3, pp 10-14.

The harbor at Cleveland, Ohio, is one of the major Great Lakes ports. Almost 20 percent of the Great Lakes' shipments of iron ore has passed through the harbor during the past 20 years. It is facing problems because of increasing bulk shipping tonnages and present constraints on ability to handle larger vessels; there are restraints at harbor entrances, river channels are winding and narrow, and bridges and damaged seawalls pose problems. The present harbor and lakefront area is described. The outer harbor area covers 1,300 acres protected by a

confirmed to be displaced with increasing concentration of slurry or diameter of pipe towards the point corresponding to the Reynolds number at which the line for laminar flow intersects the extension of the line for turbulent flow on the "factor versus Reynolds number" plot.

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1118 PAMELY-EVANS, O. G. 1969 (Aug). "Flow Measurement; Part 1: Gases/Liquids and Slurries," Control and Instrumentation, Vol 1, No. 4, pp 27-32.

An important part of costing plant operations is being able to measure flow as accurately as possible. Over 30 types of devices used to measure flow in gases, liquids, or mixtures (slurries) are discussed and displayed diagramatically. These act by measuring fractions of kinetic energy, changes with time, electromagnetic effects, or mass per unit time. Devices described range from the simple Pitot tube (with accuracies of 2 to 5 percent of full scale immediately after installation) to gate meters (able to achieve 2 percent accuracies on viscous liquids) to electromagnetic meters (with accuracies of 1 percent or better on electrically conducting slurries). A new type known as the "Swirlmeter" for gas flow measurement is described. Continuous measuring types are distinguished from intermittent measurement methods such as "salting" or "chemical" methods in which a small amount of contaminating substance is introduced and detected later downstream. It is noted that, in general, fluid flow is one of the least satisfactory industrial measurements because it is a function of physical properties of a fluid in a way that temperature and pressure are not.

1119 PASQUE, G. 1979 (Mar). "A New Form of High Accuracy Position Fixing," World Dredging and Marine Construction, Vol 15, No. 3, pp 16-18.

This article tells about the operational advantages of the newly-introduced, production line model electronic positioning device by Tellurometer, the MRD1 System. For dredging programs, this device can assure uniform coverage and maximize work time and efficiency. The system works on a low-power microwave frequency capable of sustaining repeatable accuracies of better than ±1 meter (often less than 10 cm) with a range from 100 meters to over 100 kilometers. Two or more battery-operated remote units are placed on shore to return signals to the ship-mounted master instrument. Up to six separate vessels can operate from shared remote units. Signal loss is precluded by an averaging procedure, and it is immune to signal loss simply from ship passage. It is self-calibrating, with automatic tuning, has simplified console operations, and can be installed and maintained with very little skill. For system checks, it has a self-test capability. Peripheral equipment that can be used in conjunction with the basic unit adds capabilities for echo sounding, track plotting, data recording, remote event recording, left/right indicating, or freezing the display. The system will function in temperatures from -32 degrees C to +44 degrees C. Safety is accounted for by the low-power microwave emissions and the fact that the highest system voltage is a 34-volt supply.

1120 PASTOORS, W. C. B. 1972 (Mar). "Ocean Mining Operations," World Dredging and Marine Construction, Vol 8, No. 4, pp 23-25, 28-29, 45.

The purpose of this article is to discuss the possible applications of centrifugal pumps to ocean mining. The experience gained through deeper offshore dredging for harbor approaches in unprotected waters has led to better possibilities for marine mining at great depths. After reviewing briefly the history of dredges for mining use and the use of suction dredging in offshore mining, a theoretical analysis of lifting capacity is given. Two pump conditions are compared relative to horsepower requirements, density of pump mixtures, available vacuum, and depth. Condition 1 involves having the pump placed at a constant level; at a depth of 200 feet, this becomes an expensive and inefficient method. Condition 2 involves lowering the pump proportionately with increasing depth. A number of considerations are discussed for both conditions from a dredge construction point of view. Other major topics dealt with include preparation or treatment of pump mixture, pumps with Venturi jet systems, beach and continental shelf mining (to 200 feet deep), modification of existing dredging plants, and future viewpoints. Three major methods are suggested for future deep ocean mining; they are dependent upon depth, type of materials, and compaction.

1121 __________. 1972 (Jul). "Dredging Benefits from Underwater Blasting," World Dredging and Marine Construction, Vol 8, No. 8, pp 19-22.

Underwater blasting is but one of many factors that influence quality of work and economic efficiency of dredging operations. In conjunction with selection of the dredge (if needed) to remove rock material, each blasting project needs careful appraisal to find the most economic rate for rock fragmentation. Four basic types (different methods) are described for underwater rock fragmentation: (1) the combined fragmentation/excavation method, (2) fragmentation by surface blasting, (3) shothole blasting, and (4) submarine controlled explosives engineering. The first method uses placement of charges in such a way that controlled crater excavation is the result, with no need for dredge removal of material. This method works well in soft materials but is expensive for explosives and labor costs. Savings result from the lack of need for the drilling or dredging plants. Surface blasting involves use of divers to place 50-pound boxes of explosives in a regular pattern. This method also is expensive. Shothole blasting is more usually used and economically justifiable for controlled fragmentation. This third method and that of submarine explosives engineering are discussed in more detail than the first two methods. Sections on safety precautions, bulking of rock for dredgeability, and alternative dredging methods conclude the paper.

1122 PAULSON, F. O. 1967 (May). "Hydraulic Dredge Design," Proceedings, World Dredging Conference, WODCON I, pp 39-51.

Significant highlights of hydraulic dredge design are presented. After giving a brief history since the hydraulic dredge's inception in the late nineteenth century, the key components and controls of hydraulic dredges are reviewed. As a general rule, the hydraulic dredge today is the most economical means to transport large quantities of materials. These dredges are normally self-sustaining plants, self-powered, with adequate fuel and water capacity, crew accommodations, and component reliability. The major topics discussed are the hull and superstructure, ladder, spuds, hoisting equipment, crew's quarters, cutter drive, pumps, power plants, pipelines, maintenance, automated devices, and indicating and recording instruments. Improvements in future hydraulic dredge design will encompass larger pipeline sizes, more power, dual pumps, jet boosters, more automation, more sophisticated hoist controls, abrasive resistant pumps and cutters, automated ladder controls, and load regulating devices to maintain nearly constant horsepower from diesel engines.

1123 PEKOR, C. 1973 (Oct). "Advances in Pump Application," World Dredging and Marine Construction, Vol 9, No. 12, pp 18-20.

Application engineering for centrifugal pumps pumping clear water has been well developed for many years, but for running dredge pumps, the best speed to use often has been determined on a trial-and-error basis, with heavy reliance on past experience. This article discusses factors to be considered in application of pumps to plain suction dredges. Flow velocity and "entrance losses" are discussed first, followed by head loss and friction loss. Seven significant variables have been identified as affecting frictional resistance to flow in a dredge pipe: (1) pipe diameter, (2) roughness of pipe walls, (3) specific gravity of the solids, (4) size and size distribution of the solids, (5) shape of the solid particles, (6) velocity of the mixture, and (7) viscosity of the mixture. Entrance loss can become the biggest energy consumer on the suction side of a pump. After determining suction head, operating limits must be defined; there are four of these: (1) the point of cavitation (when the impeller turns too fast relative to water velocity and pressure), (2) the point of critical velocity (when particles begin settling out and plugging may be imminent), (3) horsepower limitations, and (4) when pump speed is excessive causing unacceptable wear or dangerously high pressures on long discharge lines. Pump operating ranges are discussed in some detail and depicted graphically. Production curves are discussed as important guides in establishing the optimum pump speed and to aid in predicting production. The benefits of jet booster systems at greater depths as a powerful new dredging tool are explained.

1124 PISTILLI, A. D. 1980 (Mar). "Proliferating Regulations Stifle Commerce," World Dredging and Marine Construction, Vol 16, No. 3, pp 32-34.

This speech was given to the Management Institute, Glassboro College, New Jersey, in November of 1969; it concerns land use, industrial

development, and the bureaucracy of local, state, and national government. Bureaucrats apparently go by a "no-growth" policy; if there is no use of the land, there can be no misuse. A few years ago our industrialists could build about wherever desired. With the overreaction in the early 1970's, resulting in much environmental and land use legislation, growth is totally stifled. The result is that our standard of living is declining; productivity per man-hour is down, and energy is scarce. Many companies attempting to build industrial plants along the Delaware River in Southern New Jersey have given up after huge expenditures in trying to obtain numerous permits. Something as simple as building a "duck blind" requires five permits even if you own the land and are paying taxes. A major project like a pier requires a developer to obtain 39 permits and years of planning and studies, which sometimes are more costly than the project itself. Additional "layers of government" keep springing up, but this trend needs to be reversed. If restraints by overregulation continue, there will be zero or negative growth. Several steps are suggested to reverse the overregulation trend in New Jersey.

1125 POLHEMUS, J. H. and DUPRIEST, J. R. 1928. "Friction in Dredge Pipes," Transactions, American Society of Mechanical Engineers, Vol 50, No. 3, pp 17-22.

Data regarding head loss and friction from a field test of 29-inch, smooth dredge pipe are discussed and presented in tables and graphs. The pipe segment in which measurement took place was straight, 1,046 feet long, and floating. It consisted of 90-foot sections attached with flexible rubber sleeves. Clean water velocity was up to 20 feet per second. The testing was done prior to designing the main pump for the Port of Portland's new diesel-electric dredge "Clackamas." Pipeline velocity was measured using two electrodes and the introduction of salt solution which would alter resistance readings. Friction factors were first found by a well-known equation. Study of the data using logarithmic paper indicated that the equation could be improved if modified to have an exponent (n) of 1.75 instead of 2.00 for the water velocity term. This has long been considered by other engineers. Results of testing give a friction factor of 0.028 for 29-inch pipe in good condition, but the rubber sleeve connections may have some effect. The values given here for friction factor and n are for 29-inch pipe, and may not hold for other sizes of pipe because the head loss may not vary as 1 divided by the pipe diameter. Subsequent discussion by another author shows that the formulas may better represent actual conditions if a term for viscosity is included.

1126 POWERS, J. 1980 (Dec). "Bucket Dredging Methods and Equipment," World Dredging and Marine Construction, Vol 16, No. 12, pp 11-14.

An overview of bucket dredging vessels and equipment is presented. Bucket ladder dredges are used throughout the world for maintenance, new work, and especially for mining. Bucket dredges used in the United States are mostly of the clamshell, backhoe, and dragline types.

Another, more recent, arrival on the scene is the bucket-wheel dredge, which combines soil loosening by buckets and transport by hydraulic suction. Bucket dredges are often used because of their ability to move concentrated, heavy sediment, and because bucket ladder dredges actually can dredge above the waterline. The majority of bucket dredges operate only in calm waters. Several brands of equipment and operating dredges are described. Principal design requirements of all bucket dredges are that the buckets must be able to dislodge soil efficiently, fill completely with material, and empty rapidly and completely when inverted. References are provided for obtaining information on dredging equipment suppliers.

1127 PRICE, W. 1975 (May). "Dredge Mines 18 Million Tons of Aggregates in Ohio River," World Dredging and Marine Construction, Vol 11, No. 6, pp 40-42.

Performance specifications are discussed for "Dredge No. 16" built by Dravo Corporation. This 200-foot-long bucket ladder dredge, capable of digging to 50 feet, was put in service on the Ohio River in 1958 to meet demand for a wide variety of sizes of cleaned and crushed aggregates and sand. The dredge is equipped with 100 buckets, each with 7-cubic-foot capacity, and has a digging rate of 600 tons per hour. The dredge was designed to be able to simultaneously load four 500-ton capacity deck barges with several different gravel sizes (from 2.5- to 0.125-inch) and/or coarse or fine sand. It could also reblend the various aggregates in controlled proportions. The processing screens also are able to handle 600 tons per hour. One particular specification for gravel was that it could be passed through a media separation plant for floating out light, porous gravels, coals, wood, and debris. For sand processing, the plant had to control the gradation by removing any portion of the size range. This dredge took 1.5 years to build at a cost of about $1.5 million. Since being placed in service, it has dredged over 18 million tons in 15 years, and has met the original expectations with very few modifications or improvements.

1128 PRYCE-JONES, J. 1948 (Mar). "The Flow of Suspensions -- Thixotropy and Dilatancy," Proceedings, Durham University Philosophical Society, Vol 10, No. 6, pp 427-467.

The study of the flow of suspensions is still in its elementary stages; therefore, the lecture presented here is more of a review of a problem than a survey of established knowledge. Several factors are analyzed which are involved in the flow of suspensions of fine particles, namely, those factors which influence the relative viscosity and two closely related topics, the fluid dispersion coefficient and the degree of dispersion. Temperature effects, volume concentration of particles, mean particle size, anisotropy (shape) factor, fluid viscosity, and thixotropy are all discussed as factors contributing to suspension viscosities. Five classes of viscous liquid/suspension systems are defined, ranging from true liquids to time-dependent non-Newtonian fluids, and to dilatant fluids. Numerous experiments performed by others and by the author are used to illustrate the behavior of many types of suspensions.

1129 PURDY, G. R. and EICHHOLZ, G. G. 1959 (Dec). "A Viscometer for Mineral Suspensions," Investigation Report IR58-211, Department of Mines and Technical Surveys, Ottawa, Canada.

Development and testing is described for a simple viscometer suited to investigate the rheology of suspensions, primarily mineral slurries. In this system, a "plummet" (bronze ball, 5/16 inch in diameter) is pulled vertically through the slurry in a 34-inch-long, 0.55-inch-inside-diameter copper tube, at a rate governed by an external weight. This technique, instead of observing "free-fall velocity," lends itself to studies on the effect of shear rate on measured viscosities. The velocity of the plummet was established by means of two Geiger tubes outside the viscometer tube, which were actuated by a small radioactive source inside the plummet. Suspensions of glass balls, barite, and galena were used to compare viscosities at different rates of shear. Variations in flow characteristics, particularly the non-Newtonian nature of the barite and galena slurries, were clearly demonstrated. The design of the instrument and all test data are presented in tables and graphs. Among the conclusions are: (1) unlike barite suspensions, galena suspensions do not approach Newtonian behavior at high shear rates; (2) the degree of departure from Newtonian behavior depends on extent of particle interaction; (3) the effect of particle size on apparent viscosity depends upon extent of particle interaction; (4) particle interaction depends chiefly on particle shape; (5) suspensions having initial settling rates of less than 1 mm/min are most conveniently handled by this viscometer; and (6) the maximum percentage error is ±4 percent. Limitations and uses are provided.

Q

1130 QUINN, J. A., LAPIDUS, L., and ELGIN, J. C. 1961 (Jun). "The Mechanics of Moving Vertical Fluidized Systems; Part V: Concurrent Cogravity Flow," Journal, AICE, Vol 7, No. 2, pp 260-263.

Previous studies on vertical fluidized systems led to the recognition of a new technique for fluid-particle contacting. This article presents results of investigations to study operating characteristics for this "concurrent cogravity" type of flow. Particulate solids used in the experiments were glass spheres of 0.0184- and 0.00396-inch diameter; the fluid was water. Measurements were made of the particle concentration (or holdup) existing in a 1-inch-diameter vertical column as a function of the fluid and particle flow rates. Data for each particle size are correlated in terms of slip velocity and particle concentration. Slip velocity is demonstrated to be the same unique function of particle concentration for concurrent cogravity flow and for batch fluidization. Therefore, particle concentration and the conditions of limiting operation for concurrent cogravity flow can be predicted accurately from the batch fluidization curve.

R

1131 RACHLIN, B. 1956 (Dec). "Improved System Measures Heavy Slurry Density," Mining Engineering, Vol 8, No. 12, pp 1224-1227.

Development of a system which continuously measures density (or specific gravity) for a heavy pyrite ore-water slurry in the sulfur dioxide production process is described. The radioactive and air bubble type measurement options were discarded as infeasible. Instead, the displacer system was used, consisting only of a metal immersion unit and a means of weighing it. The detecting unit is a displacer suspended in the slurry. The changed buoyant force of the slurry on the displacer (caused by changes in specific gravity of the slurry) is then transferred to the transmitting unit. The Brown pneumatically operated differential converter unit was selected as the ideal instrument for measuring apparent change in weight of the displacer. The pneumatic signal is transferred to a continuous-chart type recorder. Five specific design requirements include: (1) continuous slurry level in the measuring chamber; (2) representative slurry being measured; (3) complete circulation so that slurry density changes can be detected quickly; (4) no clogging in the chamber; and (5) elimination of pump surges that would present measurement problems. The initial design was successful in that continuous measurement between specific gravities of 2.00 and 4.00 was achieved with no clogging. However, it was partially unsuccessful because flow surges masked densities by producing a cycling band of recordings 0.20 specific gravity units wide. Revising the chamber by adding a specially designed baffle to direct the flow reduced the maximum band of cycling to only 0.04 specific gravity units. The final design is applicable to any slurry pumpable to the sampling chamber.

1132 RADWAY, E. R. 1969 (Aug). "South Waves Ports -- Hydrographic Survey and Maintenance Dredging Techniques," Dock and Harbour Authority, Vol 50, No. 586, pp 174-176.

Advanced design and use of dredging and hydrographic equipment has made possible longer, deeper, and better controlled channels at an economic cost for the five ports of South Wales. The total dredging requirement of the South Wales ports is about 7 to 8 million tons annually. Before 1956, hydrographic surveys were carried out from row boats using lead lines and poles at low water. This was an inefficient operation. During the past 15 years, power boats with recording echo sounders have been used to cover more areas. Also prior to 1956, the basic dredging unit for both channel and in-dock dredging was a 900-cubic yard-per-hour bucket dredger and two attendant hoppers. After studying the dredging needs of the ports, several new vessels were ordered. The modernized fleet now consists of one bucket dredger, four grab dredgers, and three suction hopper dredges. There was doubt that the suction dredgers could perform well in the mud of the Severn Estuary, but they were effective. "Optimum theoretical output" is calculated for the dredges, including consideration of maintenance, locking operations,

weather conditions, distance to dumping grounds, and transfer of craft between ports. The use of the Decca Hi-Fix electronic positioning system as a general hydrographic and dredging tool is discussed. For most efficient work, the following conclusions were reached: dredgers should be of maximum size possible; the dredgers should operate 24 hours daily; modern positioning methods should be employed; and the number of vessels should be a minimum.

1133 REDDY, Y. R. and KAR, S. 1968. "Theory and Performance of Water Jet Pump," Journal, Hydraulics Division, ASCE, Vol 94, No. 5, pp 1261-1281.

An overview is presented on the design theory, applications, and history of performance of the water jet pump. From its inception in 1852 to now, maximum efficiency achieved has been 37 percent in 1965, but because of simplicity and reliability, these pumps are widely used in drilling, mining, dredging, and booster pumping. Graphical and mathematical means are used to describe pumping action, friction loss, head loss, nozzle loss, and other various losses to arrive at a representative efficiency equation. An experimental setup and test is described for testing nozzles of different diameters. Among the conclusions and recommendations put forth are the following: (1) the water jet pump should be designed to give a flow ratio of unity for maximum efficiency; (2) the maximum obtainable (theoretical) efficiency is 50 percent under ideal conditions; (3) the theoretical equation for efficiency was verified experimentally; (4) the efficiency of the design used in present testing can be improved by proper shaping of the suction flow entry; and (5) six recommended design dimensions are given to achieve maximum efficiency.

1134 REIGN, L. L., JR. 1970. "Report on Military Dredging in Vietnam," Proceedings, World Dredging Conference, WODCON III, pp 495-506.

Dredgers will be drawing lessons for years to come from the dredging projects that have been conducted in Vietnam. Beginning in 1965, increased military operations imposed immediate and enormous demands on all aspects of logistical support. Dredging was identified as being necessary in construction support of three work areas: (1) upgrading entrance channels, harbors, and cargo loading facilities; (2) developing base camps and depots; and (3) providing sand and coarse base materials for roads and airfields. The piece of equipment common to all these support tasks is the hydraulic dredge. By late 1966, the Vietnam dredging fleet consisted of 2 side-casting, 3 hopper, and 18 pipeline cutterhead dredges. In a 5-year period from 1965 to 1970, these dredges excavated 64.8 million cubic meters of materials. Even in Vietnam during wartime, land acquisition for material disposal was a problem. Many requests for disposal areas required 2 to 3 months to gain permission. Several dredging projects are described. The article concludes with four summaries about dredges that were either sunk by enemy attack or by sucking up live munitions.

1135 RICHARDSON, M. J. 1971 (Aug). "Project Management for Dredging Operations," World Dredging and Marine Construction, Vol 7, No. 9, pp 31-33.

Many dredging jobs have encountered overrun budgets and other problems because of management blunders. A relatively new system of control known as "Project Management," developed through U. S. defense contracts, is a concept that could easily be applied to dredging projects. It is a systems approach which includes control of time, money, and technical performance. All facets of the project are integrated in a manner which incorporates information feedback so that current and projected progress and problems can be evaluated in terms of management objectives, and alternative plans developed and evaluated. Each project requires one manager who is responsible for completion of the project, even though he/she must depend on people in other organizations for help. Organization of any specific project depends on the nature of the parent organization; the size, type, and duration of the project; the management philosophy; and the manager's temperament and capabilities. Variables involved in project organization and certain disadvantages of this approach are discussed. Network analyses, computer applications, and management reporting are shown as aids to implementing the system. The key to successful project management involves the efficient use of available resources.

1136 ________. 1974 (May). "Two Million Cubic Yards Dredged at Panama Canal," World Dredging and Marine Construction, Vol 10, No. 5, pp 38-41.

Work on the Panama Canal is never finished; annual maintenance dredging averages over 2 million cubic yards. The Panama Canal Company accomplishes most dredging by use of the "Mindi," a 28-inch cutter suction dredge, and the "Cascadas," a 15-cubic-yard dipper dredge. Canal depth is maintained at about 50 feet. The "Hercules," a floating crane capable of lifting 250 long tons, assists in Canal maintenance. Early history of canal excavations (by hand and earth movers) is presented along with discussion of the lock system and freshwater lakes that feed the Miraflores Locks on the Pacific end. The Panama Canal Company is self-sustaining, generating sufficient revenues to pay for all operations including maintenance dredging. The possibility of building a sea-level canal nearby is postulated. It is noted that there have been strong movements to change the treaty to allow Panama to take over the Canal.

1137 ________. 1980 (Oct). "Dredge Mining of Placer Gold in the 1980's," Proceedings, World Dredging Conference, WODCON IX, pp 809-820.

The adventurous activity of placer gold dredge mining in the 1980's is being fed by two factors: inflation coupled with economic recession and gold's floating rate as a commodity. Placer mining was rapidly developing after the turn of this century, but World War II brought everything to a halt. Technology impetus after the war went

more toward tin, rutile, and other mineral dredging. Now, with much higher value per ounce, mining projects are receiving feasibility analyses, and all old dredges are already back in operation. Data are presented to show how gross production, percent purity, and price per pound compare for dredged tin compared to dredged gold. World production of gold (metric tons and percentage) is tabulated for the countries and areas producing over 2 percent annually. Caution is given to potential miners to be careful in investing in equipment and startup without having experienced engineers perform a prospecting analysis to determine economic feasibility. Several sets of graphical cost comparison data and potential production data of high efficiency dredges are given to aid in determining feasibility. The last six gold mining dredges from the U. S. were delivered to Russia in 1947, but the 1980's may see construction of up to 200 new dredges.

1138 RICHARDSON, R. F. 1980 (Oct). "A Broad Path Sonar Sweeping System Applied to Dredging Surveys," Proceedings, World Dredging Conference, WODCON IX, pp 719-730.

Outlined herein is the instrumentation of a system developed for the Pacific Region, Public Works of Canada, to provide assurances that channel and harbor areas have been completely dredged to design depth in the Fraser River and harbors of British Columbia. Time-consuming and often hazardous techniques of using wire or bar sweeping practices to verify dredged depths can now be replaced with a wide variety of commercial electronic sounding equipment adopted and deployed to produce a wide-path sweeping system. The ultimate system that Public Works was seeking had to meet four basic technical criteria: (1) depths measured by echo sounding rather than side-scanning sonar; (2) output directly usable without computerized processing; (3) adaptable to a small launch; and (4) repair and maintenance service readily available locally. Ross Labs, Inc., met the requirements and developed a suitable system that produced a directly usable, hard-copy chart without excessive processing. It provides high detail, 100 percent bottom coverage when sweeping at 25-meter intervals, and while coping with obstructions from logging operations and fisherman. The system has been a great success, and has revealed previously missed hazards.

1139 ROBERTS, R. N. 1967 (Jul). "Pipelines for Process Slurries," Chemical Engineering, Vol 74, No. 16, pp 125-130.

Plant engineers sometimes are confronted with the need to redesign a plant slurry handling system, often less than 1,000 feet long but not in a direct path. This article presents a general method of extrapolating existing data to enable an engineer to expand or alter a system that currently is operating satisfactorily. Pumping, friction loss, pipe diameter, and slurry properties are considered. In general, this method applies to "light slurries." Slurries are defined, for purpose of this article, as "any liquid with solids present in more than trace amounts, the solids having a maximum dimension of 1/8 inch." Examples are provided for clay slurries for guidance in determining critical

velocity, maximum slurry concentration, and friction-velocity relations. Procedures for heavy slurries are briefly discussed, referencing other research. One particularly valuable graphic example shows how nominal velocity in a partially blocked pipe results in higher actual velocity and greater friction.

1140 ROBINSON, M. P. and YUCEL, O. 1971. "Sediment Transportation Mechanics; J: Transportation of Sediment in Pipes," Journal, Hydraulics Division, ASCE, Vol 97, No. HY3, pp 468-475.

This article basically consists of a discussion (critical review) of state-of-the-art sediment transport in pipes, referencing a manual prepared by a number of authors. The writers review the ideas and graphical presentations, but primarily deal with the phenomenon of critical velocity. Numerous literature references support the reviewer's contentions and clarify points where confusion exists.

1141 ROELOFSZ, F. and BRAY, R. N. 1968. "Drilling and Blasting of Submarine Rock in Relation to Dredging," Proceedings, World Dredging Conference, WODCON II, pp 449-464.

In the past, dipper dredges and rock breakers (such as the "Lobnitz needle") were used for rock dredging, and the work as a whole was slow and laborious. It is now no longer practical or economical to use such methods because of the rate and depth of port and channel development, especially is areas of high water velocities and inclement marine conditions. Drilling and blasting is often a preferred and more rapid method of fragmenting rock for dredging. A contractor performing marine blasting must take into account the type of dredge to be used. In general, dipper and grab dredges can remove the largest fragments, while trailing suction dredges can only remove much smaller fragments (upper limit of 100 kg in relatively smooth bottom areas). The mechanics of rock fragmentation by explosive force, the current practices of drilling and blasting, and the classification of geologic formations are discussed in relation to fragmentation for dredging. For most instances, the smaller the fragmented rock requirement, the smaller will be the drilling plot and the larger the explosive charge. Underwater explosives primarily consist of nitroglycerine, which produces proper fragmenting and becomes inert prior to dredging if left undetonated. Stability of drilling vessels and "coupling" explosives to the rock are two factors of importance in marine blasting. Bulking of the rock for dredging has an economic impact on the entire operation.

1142 ROMANOWITZ, C. M. 1952 (Sep). "Bucket Ladder Dredges Pay Off," Civil Engineering, pp 162-164.

An overview is presented on early dredging for placer gold in the California gold fields, followed by several other applications of bucket ladder dredges in the U. S. The earliest dredge used in California, the "Phoenix," was a failure and eventually sank. It was replaced by Yuba Company Dredges No. 1 and No. 2 in 1905. Since 1905, this company has operated 20 bucket ladder dredges for placer gold mining. Ability to

g at greater depths increased with experience; now two 18-cubic-foot cket dredges dig to 112 and 124 feet, respectively. The bucket ladder edge is considered the first equipment to be used successfully for epening harbors. Advantages of a bucket ladder dredge over a hydrau-c dredge are listed as: (1) more power and ladder weight to dig rder or tightly compacted material; (2) energy supplied delivers con-ntrated material to the surface; and (3) with belt conveyors, it can ansport materials to points far beyond the dredge. Examples are dis-ssed regarding use of bucket ladder dredges at the Panama Canal, the n fields of Malaya, on the Yuba River, and for preparing cofferdams ring early construction of Canyon Ferry Dam on the Missouri River, ntana. Working three shifts, the largest of these dredges could move 000 cubic yards of gravel daily.

43 ROMANOWITZ, C. M. 1971 (Mar). "Systems for Ocean Mining," World Dredging and Marine Construction, Vol 7, No. 4, pp 27-32.

This report focuses on placer mining by dredging, bringing to-ther old and proven dredging concepts with more current techniques. A story of floating bucket-line dredges is given, starting with the rst gold mining operation in New Zealand in 1882 and ending when the st gold dredge was shut down in California in 1968. Hydraulic and me-anical dredging systems are discussed relative to advantages and dis-vantages of each in mining operations. In digging operations where luable mineral recovery is not the objective, the hydraulic suction edge has greater capacity per dollar of invested capital than any me-anical system because the hydraulic dredge both excavates and trans-rts. Nine disadvantages of hydraulic dredges (even with cutterheads) lative to bucket dredges are provided. Examples of dredge mining for ell, removing overburden for bauxite mining, and mining for asbestos e given. Mechanical systems are described beginning with the capabil-ies of these types of dredges, and advantages of bucket-line mining edges are provided. The reasons for lack of bucket capacity increases e explained. A concluding part discusses advantages of the bucket-eel excavator.

44 ROSHCHUPKIN, D. V. 1972 (Dec). "Hydraulic Calculation of Closed, Semi-Open, and Open Cutters of Suction Dredges with Blades of Limited Width, Gidrotekhnicheskoe Stroitel'stvo, No. 12, pp 43-45.

Analysis and mathematical derivations are used to present the draulic action induced by the usual types of closed, semiopen, and en cutters used on suction dredges. The hydraulic calculation amounts a determination of the head developed by the cutter. In addition to e dynamic head, the quantity of water being delivered to the internal vity of a cutter head is another hydraulic characteristic. Blade in-ination plays a large part in determining water velocity and flow. perimental data show that velocities of water directed by cutters to-rd the mouth of suction nozzles are between 0.60 and 1.82 meters per cond, which are scouring velocities for unconsolidated sands and small

ess. Among these are the LASH (Lighter Aboard Ship) ship which loads unloads itself offshore, the container ship, and the very large ker (which some day may exceed 750,000 deadweight tons). With regard dredging for large merchant ships and the ability to dredge more less continuously and under severe sea conditions, submersible and face dredgers are discussed. A twin-hulled trailing suction dredger h built-in hoppers and accompanying hopper barges is described T ie tem is capable of working 100 percent of the time, dredging to over feet deep, and, using a wide, stable hull, the multiple suction e-intakes are adjacent and cut a swath up to 30 feet wide. Four of eight onboard pumps are in the specially designed ladders; the other r serve as boosters in the hull. Nuclear power may someday be used dredgers.

6 STEPHEN, T. W. 1972 (Jun-Jul). "An Initial Approach to the Design of Trailing-Suction Hopper Dredgers," Ship and Boat International, pp 42-48.

The trailing suction dredger is a quiet and efficient type of dging machine provided that bed material is suitable, but it is very sitive to changes in material properties. Care must be taken during ign of this type dredger to ensure operation at maximum efficiency er conditions to be encountered. The designer should be familiar h the intended use (capital or maintenance) and the port where dredg- will take place; most important, a full-scale soils investigation ds to be made. With this information, size of the hopper can be demined. Other factors such as climate, distance to disposal area, al range, wave period, minimum water depth, number of working shifts, port layout and physical restrictions have to be considered for al specifications. Formulas and design considerations are described hopper capacity and dimensions, hopper area and free surface (as y affect roll of the dredger), volume of displacement and specific vity of the mixture to be dredged, and center of gravity. Other den aspects discussed are hull weight and load distribution, dredge p power, discharge rate, and total manometric head. Diesel electric direct diesel drive systems are compared briefly.

7 STORDIAU, M. A. P., ROLAND, P. G., and VAN DAMME, L. 1981. "Soil Investigations for Dredging Projects," Dredging and Port Construction, Series II, Vol 8, No. 4.

With marine-related construction projects, there is a tendency concentrate investigative effort on proving a good foundation for uctures such as breakwaters, jetties, and quay walls, often to the lusion of studies on areas to be dredged or reclaimed. Such inattenn can be extremely costly in the short and long run. One of the st questions a dredging contractor should ask is: "What is the type quantity of material to be dredged?" This information and much more such things as site conditions, weather, and location of disposal a are fundamental factors that contribute to a proper choice of size type of dredger to be used. Marine soils investigations should have

.ow was measured. Tests were carried out at four values of H/L (sub-:rgence of pump/total height of pump). With a fixed value of H, air .ow rate was increased from 0 to the maximum available. At low flow ıtes, "slug" flow was observed for the water; as air flow increased, :ansition through several flow regimes to "froth" flow was observed. ırves are presented for air flow rate versus water volume flow rate, ıowing that a maximum point is reached for each H/L ratio, beyond ıich an increase in air flow reduces water volume flow. Theoretical ıuations predict this behavior within 10 percent. The optimum ratios ›r air flow rate to liquid volume flow rate lie between 1 and 2. It ›pears that the one-dimensional theory forms a good basis for perform-ıce analysis of air-lift pumps; however, additional data are needed for ffective slip ratios and friction factors of larger pumps.

174 STEPANOFF, A. J. 1957. Leakage, Disk Friction, and Mechanical Losses, Centrifugal and Axial Flow Pumps; Theory, Design and Application, Wiley, New York, N. Y.

This article considers the sources of three types of "losses" in everal common designs of centrifugal and axial flow pumps. It also rovides equations for calculating the losses and discusses their ef-ects on performance and relevant parameters. Leakage loss is defined s a loss of capacity through the running clearances between the rotat-ıg element and the stationary pump casing parts. It can take place in s many as seven places, depending on the pump type. Disk friction loss s the most important of all external mechanical losses; it occurs be-ween the disk and stationary walls during rotary motion. Polishing or ainting disks can reduce disk friction loss up to 20 percent. Badly usted disks may require 30 percent more power than newly machined ones. echanical losses include those of the bearings and "stuffing boxes," ut the matter of friction loss in both is of secondary importance and s affected by a large number of factors. In small pumps under unfavor-ble conditions, mechanical losses may be 2 to 3 percent or more of the rake horsepower. For high-speed, water-cooled pumps, a 1 percent loss or bearings and stuffing boxes is a good estimated average. Concluding ections of this report discuss losses versus capacity at constant speed nd advantages in operation offered by open impeller pump construction.

175 STEPHEN, T. W. 1970 (Nov). "Dredging and Floating Dredgers; Part III: Future Dredger Types," Ship and Boat International, Vol 23, No. 11, pp 16-23.

Development of dredgers over the past century has brought about ignificant changes, especially a rapid growth in size during the past ecade. Because of the continuing trend in building larger merchant hips which require deeper and deeper approach channels and port facil-ties, there will be no change in the trend of larger dredgers. The eak for dredgers may be slightly more than 25,000 deadweight tons, but eyond that size, the dredgers themselves will be limited by shallow ater and the "law of diminishing returns." Several concepts are dis-ussed with regard to modern cargo handling for improved deep-draft

pipeline transport, and miscellaneous references. The Center of Dredging Studies at Texas A&M University intends to update the bibliography at regular intervals.

1171 SOBO, S. J. 1980 (Sep). "Marina Anchors Long Beach Revitalization Project," World Dredging and Marine Construction, Vol 16, No. 9, pp 20-21.

Part of the $365 million being spent for downtown redevelopment of Long Beach, California, is going toward construction of a new marina which will double the city's marina capacity. For construction of the enclosure and protective jetties, almost 2 million cubic yards of base material is being dredged and pumped from a borrow pit area in the Los Angeles River, at a maximum distance of 8,400 feet. Originally, a 26-inch, 4,000-horsepower cutterhead suction dredge, the "Ollie Riedel," was to complete the dredging in 6 weeks. However, because of the Mt. St. Helens eruption, the "Ollie Riedel" went into emergency service for the Portland District, U. S. Army Corps of Engineers. A much older electrically driven dredge, the "John Franks," was reinstated to service to perform the work. Details are provided on the dredging operation and the configuration of the marina, with particular emphasis on providing electric power, moving the dredge beneath the Queen's Way Bridge, and material transport methods. Cost of the dredging operation was $3.7 million.

1172 SORENSEN, E. 1941. "Potential Flow Through Centrifugal Pumps and Turbines," Technical Memorandum No. 973, National Advisory Committee for Aeronautics.

In studying the flow of liquids through centrifugal pumps and turbines, the case of rotational motion is important and necessary for obtaining correct solutions to design problems. Several previous authors have used the so-called "two-dimensional flow" approach, which also is used in this theoretical discussion. However, the computation method here for obtaining the complex potential for the rotation is through the form of a definite integral rather than by a series. Application of the method is given for different flow situations. The article concludes by carrying through a numerical example. Seventeen figures and charts support the text.

1173 STENNING, A. H. and MARTIN, C. B. 1968 (Apr). "An Analytical and Experimental Study of Air-Lift Pump Performance," Journal, Engineering for Power, ASME, pp 106-110.

Earlier in the century, considerable experimental work was done on air-lift pumps for applications involving high lifts and deep submergence, but few data have been published on performance in shallow water or at high pumping rates. The investigation reported here developed a simple performance prediction method which is useful for calculating the major dimensions and air requirements of air-lift pumps operating in water up to 30 feet deep. Experiments were carried out using a model air-lift pump with a 1.00-inch inside diameter and a standpipe in which

1168 SMITH, S. E. 1980 (Oct). "Jet Eductors as Suction Assist Devices for Dredge Pumps," Proceedings, World Dredging Conference, WODCON IX, pp 379-388.

Jet eductors offer the potential to increase production of dredge pump systems. Through experimentation and use of computer technology, most pumping systems can be analyzed prior to installation of a jet eductor to predetermine required flow and pressure. The discussion in this article gives current jet eductor theory coupled with computer aided analysis of jet eductor and centrifugal dredge pump systems. Dredging operations before and after installation of an eductor are compared. Similarily, data are presented on requirements of a "dredge pump only" system which would be needed to match capabilities of the combined system. The effects of jet eductor assistance on pump performance curves are exhibited. Further discussion includes topics of pump speed selection, horsepower requirements, and cavitation. One of the many advantages of jet eductors is extending economical dredging depth. Jet eductors also increase potential production, and allow varying discharge concentration simply by controlling injected flow. Major disadvantages include low hydraulic efficiency, smaller passages through the eductor suction and venturi, and difficulty of installation and maintenance. Suction line winches may have to be increased in size.

1169 SMOLDYREV, A. Y. and SAFONOV, Y. K. 1979. "Pipeline Transport of Concentrated Slurries," Translated from Russian by Albert L. Peabody, Terraspace, Inc., Annapolis, Md.

The design and construction characteristics of installations used for transporting concentrated slurries are examined in this book. Included in the analyses are the broad subjects of range of application, technological features, and service requirements. Technical data and design drawings are presented for components such as pumps, mixers, feeders, and a variety of other devices. The mixtures considered here have one common feature, they manifest an initial shear stress. Most of them do not settle out even at low speeds or when stopped. Studies described deal mainly with flow and rheological characteristics of slurries with viscous-elastic properties. Time dependent, non-Newtonian slurry characteristics are not emphasized in this book. Among topics covered in the five chapters are classifications of slurries, methods of determining rheological properties (viscometers), flow modes of slurries, hydraulic resistances, equipment for slurry preparation, equipment components for pipeline transport, and experience in applications (fibers, dispersed solids, production wastes, slurries in agriculture, and construction materials). The final chapter covers planning and design of pipelines, and gives examples of methods for calculating necessary pipeline parameters.

1170 SNIDER, R. H. 1969 (Sep). "Bibliography on Dredging," Sea Grant Publication No. 203, Texas A&M University, Sea Grant Program.

A nonannotated bibliography provides 238 entries concerning five general dredging topics: dredge pumps, dredging vessels, ocean mining,

turbidity limits for the river water, while at the same time protecting the onboard equipment, led to redesigning the dredge. One of the greatest equipment concerns was in controlling the return of the much heavier bucket (14,000 pounds) to 50 feet deep. Instead of using a continuous breaking operation, a powered return system was installed. All major pieces of equipment are described. Once in operation, each dredging cycle took 79 seconds, of which 6 seconds were used to drain free water from the bucket. The new system reduced turbidity by 30 percent and maintenance became almost negligible.

1166 SMITH, E. 1973 (Oct). "Pump Rebuilding Allows Design Changes," World Dredging and Marine Construction, Vol 9, No. 12, pp 28-31.

A progressive maintenance program by dredging companies, including pump rebuilding, can make a big difference in production and cost, and in winning or losing contracts. Over the years, welding equipment and new alloys have been introduced to the dredging industry. Teledyne McKay's fully automated system for rebuilding pump shells is discussed here. It was the first introduction of such a system and the first successful use of reliable, self-shielded, hard surfacing wire. Teledyne McKay uses a two-wire system, one wire to do the major buildup and a second, more resistant wire, for the final 1 inch of thickness. Alloys and pump shells are compared with regard to wear and ease of rebuilding. Average cost for rebuilding is between one-half and two-thirds that of a new pump, with equal or greater wear life. Most of the major dredging companies are now rebuilding pump shells, sometimes several times for the same shell. Manganese shells are the most difficult and expensive to rebuild. Case histories of rebuilt pumps using Teledyne McKay's Dredge-O-Matic Mark IV System show that these rebuilt pumps will outwear new pumps regardless of their allow content.

1167 SMITH, J. H. 1979 (Jul). "Hydraulic Transients and Your Pumps," World Dredging and Marine Construction, Vol 15, No. 7, pp 24-27.

Several systems are described for protecting oil, water, and fuel pumps, or other pumps conveying nonabrasive liquids and slurries. Conditions encountered during unsteady flow, such as shock, surge, waterhammer, and pulsation are the "hydraulic transients" against which protection measures must be provided: The most common causes of these transients are opening, closing, or regulating valves; and starting or stopping pumps. Among the means of controlling transients described herein are simple baffles, pipe enlargements, suction stabilizers, acoustic isolation, gas-filled and flow-through pulsation dampeners, and hydropneumatic surge arrestors. Numerous configurations and sizes of such devices can be employed for proper control. The modes of operation of pulsation dampeners and hydropneumatic surge arrestors are described. Good engineering practice dictates that these devices be designed into each system initially. Computer programs are available to fit the right set of devices to a system.

depositing dredged material. The most difficult predictions using hydraulic models are those of scour and shoaling of sediments, and dilution and flushing of pollutants. Modelling is a powerful tool for the public and as a research method. The greatest shortcoming of using a hydraulic model is its high cost for construction and verification. Two examples are provided: The Galveston Harbor entrance (concerning primarily engineering problems), and the Lake Pontchartrain model (concerning environmental effects, particularly of salinity, on the Lake Pontchartrain fisheries).

1163 SIMON, A. L. 1964 (Feb). "Hydraulic Design of Slurry Pipes," Water and Sewage Works, Vol 111, No. 2, pp 98-99.

A set of equations and a nomogram are presented to aid in design of pipeline systems for slurry flow. Included are equations for determining the Reynolds number, pipe diameter for a given quantity and quality of a slurry, loss of energy due to pipe friction, and a correction coefficient (Z), which is a function of the parameters of concentration of the transported solid. In practical application, care should be used in recommending greater than necessary design velocity because of the erosive actions of slurries at bends and on the bottoms of pipes.

1164 SLOTTA, L. S. 1978 (Oct). "Flow Visualization Techniques Used in Dredge Cutterhead Evaluation," Proceedings, World Dredging Confernece, WODCON II, pp 56-77.

Experimental studies of methods for improving the efficiency of dredge cutterheads are described. Hydraulic model tests (using 1/15-scale plastic cutterhead models) were employed to simulate the flow conditions near and within the rotating heads. The flow comparison tests were to illustrate specifically the flow patterns of suction withdrawal both for a stationary and moving cutterhead. Electrolytically generated hydrogen bubbles (in salt water) and a movie camera were used to record cutterhead motions and water flow. The intent of testing was to show the effectiveness of the cutting/lifting of material and whether the cut material is satisfactorily pumped away or is partially scattered by the rotating cutterhead. Discharge performance tests were run with synthetic granular material for quantitative evaluation of model modifications. Among other relevant topics discussed are scaling factors for prototypes and the motion of individual particles in a turbulent flowing field. More research and reliable data from operational dredges will be required to substantiate the performance suggested.

1165 SMITH, C. A., JR. 1974 (Jun). "Small Class Clamshell Dredge Works on Big Class Projects," World Dredging and Marine Construction, Vol 10, No. 6, pp 36-39.

After many years of trial and error, a small clamshell grab dredge has been developed through design innovations to more than double its initial output and perform like a big class dredge. The dredge worked in a sand and gravel deposit on the Upper Allegheny River in Pennsylvania. The necessity to reach greater depth and not exceed

This article is a follow-up to an earlier article, which presented a theoretical interpretation of the flow of suspensions including flow regimes when the effects of fluid turbulence are relatively insignificant. In this article, a theoretical method for predicting energy losses is presented for the situation in which the suspending action of fluid turbulence is dominant. The turbulent flow is analyzed by assuming that the suspensions behave as variable-density, single-phase fluids. Friction factors were found to be dependent upon distribution of solid particles in a conduit as well as upon the Reynolds number. Comparison of the prediction model with experimental measurements (using two sizes of sand and 100- to 150-mesh zircon and nickel) indicates that, as long as turbulent suspension of solid particles takes place, the model is a useful alternative to the empirical Durand equation for pipeline design. It is noted that high local concentrations of solid particles (35 to 40 percent by volume) would be expected to produce higher eddy viscosities and friction factors than predicted by this model.

1161 SHOOK, C. A. ET AL. 1968 (Aug). "Flow of Suspensions in Pipelines; Part 2, Two Mechanisms of Particle Suspension," Canadian Journal, Chemical Engineering, Vol 46, No. 4, pp 238-244.

Experimental observations of the distributions of solids in pipeline flow were carried out with regard to investigating mechanisms of suspension for a broad range of particle properties and experimental conditions. Two mechanisms of particle suspension are discussed theoretically. An apparatus is described for measuring average solids concentration for pipe cross sections. Materials used in experiments included 80- to 100-mesh sand, 100- to 150-mesh nickel, 24- to 28-mesh sand, and 40- to 50-mesh sand. Data were obtained for constructing curves of volumetric transport concentration (q) versus distance from bottom of channel (y) and for q-y values. Analysis of all data indicate that turbulent suspension of particles appeared to occur where the concentration of solids particles was low, particle diameter was small (less than 0.2 mm), and the ratio of the settling velocity of particles to the friction velocity of the flow was less than 0.2. Where these criteria were not met, concentration profiles deviated significantly from the shape associated with turbulent suspension. These deviations are attributed to the effect of particle interactions investigated by Bagnold.

1162 SIMMONS, H. B. 1973 (Aug). "Benefits of Hydraulic Models Told," World Dredging and Marine Construction, Vol 9, No. 10, pp 19-20.

Hydraulic models have been used many times for solving problems involving estuarine physical processes. Advantages and disadvantages of hydraulic models are discussed. Only the hydraulic model is capable of simulating fluid flows having variable densities in three dimensions. The hydraulic model can show currents in their proper distributions, with temporal variation at a given point. Among changes which can be studied using such models are qualitative scour and shoaling, discharges, waves, beach changes, dilution and flushing of pollutants, propagation of hurricane or tsunami surges, and shoaling resulting from

sediment concentration that can be transported, rate of pipe abrasion, and rate of particle attrition. From the literature and analyses reviewed, it is obvious that many critical issues are far from settled. One major shortcoming is the lack of data for large pipes (12-inch diameter or larger). Data from smaller pipe systems are so inconsistent and contain such scatter that design criteria cannot be defined precisely. Competitive industries appear to be guarding in secrecy much of the pertinent data. Equations reviewed from Eastern European journals involve too many "to be determined coefficients," thus limiting their usefulness.

1158 SHIPLEY, L. E. 1957 (May). "How to Find Percent of Solids in a Slurry," Chemical Engineering, Vol 64, p 294.

A simplified equation is provided for finding the percentage of solids in a slurry. The method has been used in the ceramics industry for generations and is known as Brongniart's formula. The method requires no graphical work and applies to either the English or metric system. The formula is derived as follows: let P equal the weight of any volume (V) of slurry. Then P equals the sum of the weight (D) of the solids present, plus the weight (W) of an equal volume (V) of water, minus the weight (D/G) of the water displaced by the solid. G is the true specific gravity of the solid. By rearranging terms, D (weight of the solids present) is shown to equal $[(P - W)G]/G - 1$. When the liquid is not water, the formula becomes $[(P - W)G]/G - p$, where p is the specific gravity of the liquid.

1159 SHOOK, C. A. and DANIEL, S. M. 1965 (Apr). "Flow of Suspensions of Solids in Pipelines; Part 1, Flow with a Stable Stationary Deposit," Canadian Journal, Chemical Engineering, Vol 43, No. 2, pp 56-61.

Considerable knowledge exists about the flow of suspensions in pipelines, but proposed correlations have been mostly empirical. A body of theoretical and semiempirical knowledge has been developed by Bagnold, and continued efforts on his approach are reported here. Using Bagnold's concepts of dilatant suspension behavior, an equation is derived for the hydraulic gradient necessary to transport solids in a two-dimensional channel where suspension arises from the "Bagnold dispersive stress." This stress is the characteristic pressure of dilatant suspensions resulting from the process of momentum transfers between successive layers of the solid-fluid mixture. The equation has been tested for the case where a stationary bed of solids exists and clear fluid is present on top of the channel. The empirical constant in the equation was found to agree with that obtained by Bagnold for shear in an annulus. The equation also agrees well with Abbott's empirical equation obtained with a circular pipe.

1160 ________. 1969 (Apr). "A Variable-Density Model of the Pipeline Flow of Suspensions," Canadian Journal, Chemical Engineering, Vol 47, No. 2, pp 196-200.

is designed for mooring in 35 feet of water seaward of the jetties forming the entrance to Mission Bay. It will reduce wave height from 6.5 to 3 feet. Seven attributes possessed by the TFB system are not shared by other systems; these are discussed briefly. Among four reasons given for considering temporary wave protection, dredging is one of the most important, including beach replenishment dredging, offshore mineral dredging, cutting underwater trenches, and protecting floating pipelines. The system costs about $2200 per front foot (for a system with 25 rows of floats). Contract wave abatement may become a new type of marine service offered with the modular system described here. The system components are transportable by truck or can be towed on water in large configurations.

1156 SEYMOUR, R. J., HIGGINS, A. L., and BOTHMAN, D. P. 1979 (Jun). "Tracked Vehicle Developed for Nearshore Continuous Profiles," World Dredging and Marine Construction, Vol 15, No. 6, pp 19-22.

The ability to correlate wave parameters with offshore sand transport rates requires technological advances to make accurate profiles from the dry beach through and beyond the breaker line under storm wave conditions. A tracked unmanned vehicle was developed to meet this need through funding by the Naval Ocean Systems Center, San Diego, California. Individuals with stadia rods or small boats cannot operate satisfactorily in high waves; therefore, a standard small tractor was modified for watertight operations. Through attachment to an umbilical line which carries power and reansmits data to shore, this vehicle can reach to 450 meters offshore in water up to 10 meters deep. Design of the tractor, data measuring system, and data handling system are described. Calibration during testing involved attaching a stadia rod to the top of the vessel, stopping it every 5 meters for a comparative measurement. The two test profiles using the automated and visual system are practically identical. In actual use, the stadia rod will be detached. Onboard instrumentation includes a two-axis vertical gyroscope, a flux gate compass, and an odometer for each tread. During testing the vehicle exhibited no slippage, even on steep or soft beach slopes. In addition, no vertical elevation changes were indicated when the tractor remained stopped for long intervals under breakers greater than one meter in height.

1157 SHEN, H. W. ET AL. 1970 (Jul). "Sediment Transportation Mechanics; J: Transportation of Sediment in Pipes," Journal, Hydraulics Division, ASCE, Vol 96, No. HY7, pp 1503-1538.

Transportation of sediment (noncohesive solids) mixed with fluids in pipelines has a wide variety of applications. Objectives of this article are to: (1) present a survey of existing knowledge on transport of sediment in pipes; (2) examine similarities and differences of previous findings; and (3) suggest design criteria based on the present status of knowledge. Four regimes of solid-fluid flows are considered: homogeneous flow, heterogeneous flow, saltation, and stationary bed flow. Important design parameters covered include head (energy) losses,

Results are reported on apparent viscosity testing of six finely ground minerals: quartz, feldspar, calcite, gypsum, muscovite mica, and amorphous glass. Three types of viscosimeters were tried before reliable results were obtained with a relatively simple orifice type consistometer. Size fractions of from 5 to 50 microns (average diameter) were pulped with water at suspension concentrations of 15 to 60 percent for each mineral. Testing was performed on single size fractions and for mixed sizes at various pulp concentrations. From the experimental data, it was shown that viscosity induced by all of the substances is small at 35 percent solids or lower, regardless of particle size, cleavage, shape, or crystallinity. At higher pulp solids, the angularity of the mineral had a marked influence. The research disproved the generally held concept that fineness of particles is a major cause of viscosity (for example, viscosity of mica suspensions increased from 5 to 100 centipoises when pulp concentration was increased from 35 to 40 percent). Viscosity because of size, angularity, and crystallinity of the six minerals tested is not significant in dilute situations, but becomes significant when mineral suspensions contain over 35 to 45 percent solids. Viscosity of mineral pulps is not a simple function of particle size and pulp concentration.

1154 SCHMIDT, F. J. 1979 (Sep). "Notes on Maintenance Dredging," World Dredging and Marine Construction, Vol 15, No. 9, pp 16-21.

If our ports and waterways are to be kept open, and stagnation of our inland lakes and canals is to be eliminated, maintenance dredging must continue. Eight types of maintenance dredging plant are described, along with equipment and mode of operation, geographical areas in which they are used, and types of materials for which they are suited. The maintenance dredges discussed include plain suction, dustpan, dipper (briefly mentioning clamshell), dragline, Swintek ladder with suction, hopper, side-caster, swinging ladder cutterhead (for narrow inland channels), and cutterhead types. It is noted that the cutterhead dredge is probably the most widely used for maintenance, varying from 6- to 40-inch-diameter discharges. The cutterhead is used on all types of materials, from silt and fine sand to coral, limestone, "trap rock," and even sticky clay. The hopper type is mainly a seagoing vessel used primarily for ports and approach channels. Davits and dustpan dredge heads are considered in more detail than most on-board equipment.

1155 SEYMOUR, R. J. 1976 (Jul). "TFB: A Dredging Bonanza," World Dredging and Marine Construction, Vol 12, No. 8, pp 16-18.

The tethered float breakwater (TFB) is a portable wave dissipating system composed of an array of ballasted, 5-foot-diameter floats interconnected by wire or synthetic ropes. It can operate completely free floating, but for long-term installation it must be anchored. However, anchoring can be in deep water, thereby giving this system an advantage over other wave protection systems. A feasibility demonstration installation was put in place in San Diego Bay in 1975, and an ocean scale breakwater should be complete in 1977. The demonstration system

The engineering feasibility of dredging projects is considered with the major emphasis on economic viability. A review of types of dredging works and several dredging plants are first presented. Bucket dredges are not self-propelled, and towage and insurance are expensive parts of an operation using these plants. Suction dredges, especially trailing, hopper, and cutter dredges, require considerable initial capital, but some of these can move great quantities of materials economically over long distances and behave more like ships because they do not work from anchors or "head lines." Among the parameters reviewed that influence a project scheme are politics, plant availability, time factors, tidal and current conditions, geological factors, and meteorological factors. Survey information before and during all dredging operations is absolutely essential to the success of a project. Electronic positioning and bottom profiling systems can contribute substantially to a dredging program. With regard to geophysical exploration, great care must be taken to select the best method related to a site's geological conditions. A table is provided which shows relative performance characteristics of five types of dredgers operating under various conditions of sea state (swell and current), weather, operating conditions (inshore or offshore), and geological conditions.

1152 SAUERWEIN, K. and HOSSNER, R. 1958. "Investigations of Pneumatic and Hydraulic Conveying of Fine Coal by Tracer Methods," Proceedings, Second United Nations International Conference on the Peaceful Uses of Atomic Energy, Vol 19, The Uses of Isotopes: Industrial Use, pp 338-341.

Two experiments are described in which a radioactive tracer is used to solve problems in pneumatic and hydraulic conveyance of coal particles. Pneumatic conveying of coal from deep pits requires knowledge of the velocity of coal grains under controlled conditions to design plants more economically and reliably. A closed pneumatic system was installed in a deep pit, extending 335 meters to the surface. Radioactive bromine-labelled coal grains of between 0.7 and 5.2 grams were inserted into the upward flow of coal, and their velocity was measured by using Geiger tubes set 2 meters apart (tolerance of measurement was 5 milliseconds). Velocities of four different size ranges of coal grains were repeatedly measured at heights from 8 to 310 meters above the underground pneumatic mixing chamber. Data are tabulated and shown graphically. A similar experiment was carried out in a horizontal hydraulic system. Both experiments proved very useful in accurately determining particle velocities. The isotope of bromine chosen was selected because of its high gamma activity, high specific activity, ease of solubility in an organic glue for labelling coal grains, and because of its relative short half-life (35.9 hours) for safety.

1153 SCHACK, C. H., DEAN, K. C., and MOLLOY, S. M. 1957. "Measurement and Nature of the Apparent Viscosity of Water Suspensions of Some Common Minerals," Report of Investigations 5334, U. S. Department of the Interior, Bureau of Mines.

of the nozzle exit from the throat entrance to produce high efficiencies; and (5) increasing the nozzle spacing improved the cavitation performance of the pumps.

1149 SANTI, G. 1971 (Jun). "Trenching and Dredging in Deep Water," Ocean Industry, Vol 6, No. 6, pp 30-31.

Sub Sea Oil Services of Milan, Italy, has been instrumental in developing new underwater dredging and trenching equipment that can operate in depths beyond those of conventional dredges. The S23 manned submersible cutter dredge was built to bury large diameter pipelines in deep water (up to 200 feet). A single diver-operator can vary depth of cut from 0 to 8 feet and width from 6 to 15 feet, working at a forward speed of up to 420 feet per hour while handling 250 cubic yards per hour of material. The S23 is buoyant for towing to a site. Once on site, ballast tanks are filled and the craft submerges, attached by a tether to a support vessel. A machine weight of 0 to 50 tons can be employed on the ocean floor. The cutter and suction nozzle are carried on an extension arm at the front and operate hydraulically. The operator uses instruments to work because turbidity obscures the cutter head. The machine can cut hard material and deposits its cuttings to either side of the trench through two vertical pipes. The entire machine is operated using three 60-horsepower, 440-volt electric motors driving hydraulic pumps. Two other pieces of equipment, another pipeline trencher and a submersible shot-hole drill, also are mentioned.

1150 SARGENT, J. H. 1972. "Investigations for Dredging Projects," Terra et Aqua, Vol 3, No. 4, pp 10-15.

The scope of technical data needed to properly carry out dredging projects can be broadly categorized as oceanographic, meteorological, hydrological, and geological. This article considers the geological aspects. Of all factors which affect dredging or reclamation work, the materials to be met (soil and rock conditions) probably are the most important. Classification of soils and rock by various international groups, such as PIANC (Permanent International Association of Navigation Congresses), is discussed. It is noted that the cost ratio of dredging rock versus dredging unconsolidated sediments is on the order of 10:1 or greater. Methods of investigation are described from the standpoint of sampling equipment, sample perservation and transport, soil versus rock sampling, and laboratory methods. Rock drilling techniques are discussed along with the use of penetrometers, vane tests, and dynamic penetration tests. Of particular interest when considering soil samples are the parameters of particle size distribution, density, and shear strength; for rocks the important parameters are porosity and compressive and tensile strengths. Field techniques in the future should include more geotechnical methods and more "on-site" studies of the soil and rock conditions.

1151 __________. 1973 (Apr). "An Outline of Feasibility Study Requirements for Dredging Projects," Civil Engineering and Public Works Review, Vol 68, No. 80, pp 333-338.

1147 SALEM, A. M. and KRIZEK, R. J. 1973 (Nov). "Consolidation Characteristics of Dredging Slurries," Journal, Waterways, Harbors and Coastal Engineering Division, ASCE, pp 439-457.

This article describes studies on aqueous slurries, and is aimed at providing means to evaluate the consolidation characteristics of typical dredged materials. The methods are important for those faced with the task of developing benefit-cost analyses for diked disposal of slurries, and for determining the long-range behavior of landfill sites composed of such materials. A new apparatus known as the "slurry consolidometer" is discussed relative to its design, operation, and resulting data. Samples used are representative of several methods of dredging and various parts of the dredging cycle. Initial water content of the samples ranged about 60 to 90 percent. The equipment is designed to artificially speed up the slurry consolidation process, and results in values of void ratio versus time. Convenient empirical equations are derived to relate consolidation characteristics (compression index, coefficient of consolidation, coefficient of volume compressibility, and coefficient of permeability) of materials to their void ratios and consolidation pressures; however, caution should be used in applying these equations because the range of variation is quite large for a given property. The method shown is useful for studying consolidation when materials are too soft, too fluid, or both, to test in the conventional manner.

1148 SANGER, N. L. 1970 (Mar). "An Experimental Investigation of Several Low-Area-Ratio Water Jet Pumps," Journal, Basic Engineering, pp 11-20.

The water jet pump is used frequently as a booster pump in many systems because of its simplicity, reliability, and good performance at low net positive suction head. Experiments using several low-area-ratio jet pumps are described with respect to performance as the geometrical variables of area ratio, throat length, and nozzle spacing were changed. Diffuser geometry also was varied, but to a lesser degree. Experimental values of efficiency and head ratio were compared to a one-dimensional theoretical prediction model previously found to be applicable to moderate- and high-area-ratio pumps. Two cavitation prediction parameters were developed and compared to experimental data. Seven major results of testing are reported, among these are: (1) low-area-ratio jet pumps were capable of achieving relatively high efficiencies (31.5 to 38.7 percent); (2) a previously developed one-dimensional analysis was capable of predicting noncavitating efficiency and head ratio for low-area-ratio pumps; (3) pumps with throat lengths of 5.66 times the diameter performed well while those with longer throats were penalized by friction losses; (4) the best-efficiency nozzle position was found to be dependent on throat length--short throat pumps required large spacing

gravel. Thus, flow directed by the cutter is able to transport sand, gravel, and gravel-sand muds toward the suction nozzle (the zone of active suctioning of the material).

1145 ROSHCHUPKIN, D. V. 1978 (Jun). "Classification of Soils According to the Difficulty of Their Excavation by Suction Dredges (Discussion of Construction Specifications)," Gidrotekhnicheskoe Stroitel'stvo, No. 6, pp 34-36.

A proposed soil classification table is exhibited, based on the difficulty of excavation by suction dredges. Unity of methodological approach is emphasized. Definiencies in several other proposed soil classification schemes for dredging purposes are shown. Any more comprehensive proposed scheme should reflect the characteristics of the interaction of the soil and dredge. Factors such as granulometric composition, density, water content, strength, indices of erodibility, and hydraulic transportability should be taken into account. With respect to dredge type, water output, suction, transporting ability, type of intake device, and method of excavation should be accounted for. It is suggested that the proposed soil classification can serve as a basic and guide for compiling a complete classification.

1146 RYDEBRANT, G. 1968 (Oct). "Modern Rock Drilling and Blasting Technique for Underwater Excavations," Proceedings, World Dredging Conference, WODCON II, pp 338-372.

Underwater rock blasting differs from ordinary bench blasting because factors such as waves, wind, tide, and saltwater affect the work differently. Drilling from platforms for placing charges is much preferred over the use of divers for several reasons: up to 10 times more drilling per shift can be accomplished; vision of divers is obscurred, making it difficult to follow drilling patterns; and smaller explosive rounds must be used or the explosive will be under water too long. Drilling platforms and drilling methods are discribed at some length. Among the topics covered are floating platforms, platforms with legs, wagon drills, drills with extension rods and tubes, drilling patterns, and drill performance. Selection of explosives depends often on safety factors and economics. For most underwater blasting, a dynamite containing 35 to 40 percent nitroglycerine is most suitable. Discussions of mechanisms for ignition, charging, checking the firing system, and the condensor blasting machine conclude this condensed description of the overburden drilling system. The text is supported by 20 figures showing drilling platforms, patterns, bits, and associated blasting equipment.

a pre-planned, regular program. Vertical accuracy should be at least 50 to 100 times more precise than in the horizontal direction. Selection of a vertical datum should be very accurate for estimates of total quantities to be dredged. Boring techniques in the field are discussed for both soft and hard materials. Field tests should obtain undisturbed vertical samples for a thorough laboratory analysis, and also should include field analysis of shear strength, permeability, and compactness. A brief summary of laboratory testing is outlined for seven commonly encountered soil types: clays, peats and organic soils, silts, sands, gravels, boulders and cobbles, and solid bedrock. Unusually large, complex, or difficult projects may justify "trial dredging."

1178 STRIPLING, L. B. and ACOSTA, A. J. 1962. "Cavitation in Turbopumps; Part 1," Journal Basic Engineering, ASME, Series D, Vol 84, No. 3, pp 326-338.

Speed in pumps cannot be increased indefinitely because cavitation limits their performance; this is true not only for liquid-rocket propulsion systems, but for the petroleum and hydroelectric industries as well. A knowledge of conditions under which cavitation reduces performance is extremely important to equipment designers. The "free streamline theory" discussed here appears to be a good guide in determining cavitation limits of simplified pumping configurations, and is especially useful as a basis for correlating experimental tests. Cavitation models and problem formulation are first described, followed by problem solution and a discussion of several cases. Mixing loss and cavity shape are given special emphasis. Free streamline flow through a cascade of flat plates is taken as the simplified model of the cavitation process in a helical inducer pump. Length and thickness of the resulting "cavity" are determined as functions of blade geometry and cavitation parameter. Loss coefficients resulting from the cavitation are estimated, and representative cavity shapes are calculated to aid in designing the leading edge shape of blades.

1179 STYER, F. W., PIETERS, E. T., and HATHEWAY, D. J. 1979 (Sep). "Practical Automated Dredge Surveys," World Dredging and Marine Construction, Vol 15, No. 9, pp 29-33.

Automated hydrographic survey methods employed by Gardline Hydrographic Surveys, Inc., for the St. Louis District, U. S. Army Corps of Engineers, are described for work primarily on the Mississippi River. A crew of three using a shallow-draft vessel (23 feet long) performed all shore control, bathymetry, and final charting on site each day for areas to be dredged by cutterhead and dustpan suction dredges. Average size of each dredge site was 3,000 feet long by 300 feet wide. The merit of automation became very apparent when equipment failure mandated using tradional methods for a 3-week period. Equipment and practical advantages of the automated methods are discussed for initial survey operations, dredge survey operations and support, and data reduction for volume concentration. Accuracy in repeatability was of major concern for volume computations, while geographical precision could be obtained

later when time permitted more accurate river traverses. Extreme care had to be used in monitoring river levels because an error of just one-tenth of a foot over a 3,000- by 300-foot dredge site results in a volume error of over 3,000 cubic yards. One advantage of on-board automation was that erroneous depth soundings or positioning errors could be corrected while still on site. Techniques of data collection and reduction were tested exhaustively for efficiency and precision, with the objective of designing standard practices and incorporating allowances for environmental factors to the extent possible.

1180 SUNDARESAN, M. 1976 (Feb). "New India-Built Dredgers," Ship and Boat International, Vol 29, No. 1, pp 45-46.

Dimensions, specifications, and dredging operability are presented for a new, nonpropelled, cutter-suction dredge built for the Indian Ministry of Shipping and Transport by Mazagon Dock Limited of Bombay. The dredger is capable of dredging firmly bonded clay, sand, and soft rock, and can operate in open waters exposed to swell. Dredging to 22 meters below water is possible. The cutter drive is situated at the upper end of the steel ladder. Two interchangeable cutters are provided, and two dredge pumps are installed to work singly or in parallel. Each dredge pump is driven by diesel engines developing 2,300 horsepower at 900 rpm. When working with one dredge pump, the design output is 1,150 cubic meters per hour of solids on a discharge pipe 800 mm in diameter and 1,000 meters long. One man, using comprehensive dredging instruments, can operate dredge pumps, cutter drive, and other gear. The dredger is designed to be towed in normal sea conditions all around the Indian coast with spuds stowed on top deck, the anchor booms and anchors on deck, and the ladder wedged to the pontoon hull.

1181 SZAWERNOWSKI, P. 1965. "Efficiency of Dredging Operations in Tidal Estuaries," Proceedings, Twenty-First International Navigation Congress, PIANC, pp 177-185.

Criteria are assessed by which efficiency of dredging operations in tidal estuaries can be measured. A single criterion, such as "increase of navigable depth on the limiting bar" is insufficient because the same final effects can be obtained with different amounts of dredging works (that is, different total volumes extracted). Criteria based on taking maximum advantage of the energy of river currents and tides by a minimum of applied dredging is proposed, and the influence of tidal phenomena as determinant and dominant factors in estuarine dredging success is discussed. Assessing the efficiency of dredging for on-the-spot corrections and for large or seasonally repeated dredging projects is explained. Conclusions show that rational use of tidal estuary currents (energy) during dredging operations can be assessed. Frequent valid surveys of depth changes during dredging allow more accurate evaluations of results and predictions of the right time and site of dredging intervention.

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1182 TATSUMI, H. 1974. "Large-Scale Reclamation on Soft Subsoil," Proceedings, World Dredging Conference, WODCON VI, pp 61-138.

An immense reclamation project at two work sites in Japan is described. The total area being reclaimed for industrial zoning involved 1.78 million square meters. The soils existing in the area are the poorest for development on the Japanese islands, but "there is no progress without efforts to discover and clarify unknown possibilities." Among the features of the project presented here are geological formations, soil characteristics, and physical layout of the sites. Problems encountered with regard to the area soils include settlement and sinking, poor bearing capacity, and shrink/swell. Calculations for engineering the reclamation and postreclamation work are shown. A program of soil transport by sea and overland, and the use of "pit sand," is described. Among the floating construction plants described for this massive project are pusher barges, reclaimer barges, suction dredgers, grab dredgers, "ooze pump dredgers," and floating crane. A prefabricated steel cell method for use on soft soils is discussed with regard to advantages and disadvantages. Numerous charts, tables, photographs, maps, and drawings support the discussions. Thus far, work has progressed satisfactorily without appreciable deviation from original plans.

1183 TAYLOR, G. 1954. "The Dispersion of Matter in Turbulent Flow Through a Pipe," Proceedings, Royal Society, England, Series A, Vol 223, pp 446-468.

It has been shown recently that when a soluble substance is injected into a tube flowing with liquid in laminar (streamline) motion, it is dispersed in the fluid relative to a point of reference moving with the mean flow speed. Apparently, it also is affected by a virtual coefficient of diffusion which depends on pipe size, mean flow speed, and coefficient of molecular diffusion of the injected material. The object of the studies described here is to discover whether an analagous situation occurs when applied to dispersion in a fluid in turbulent flow. Another goal is to predict the value of the coefficient of diffusion and to show how it is connected with previously measured quantities related to turbulent flow in pipes. Mechanics of dispersion are described taking into account pipe smoothness. Results of experiments are explained using rapid brine injection in long, straight, smooth pipes of 3/8-inch diameter and in artificially roughened and curved pipe of the same diameter. Other studies reported in the literature are reviewed, including one in which radioactive tracer was injected into a 10-inch pipe that extended 182 miles. The theoretical prediction for diffusion was verified for both rough and smooth pipes. A small amount of curvature was found to increase dispersion greatly.

1184 THOMAS, D. G. 1961 (Sep). "Transport Characteristics of Suspensions; II: Minimum Transport Velocity for Flocculated Suspensions in Horizontal Pipes," Journal, AICE, Vol 7, No. 3, pp 423-430.

This article describes studies and presents experimental data concerning "minimum transport velocity" of flocculated suspensions of kaolin and thorium oxide flowing in glass pipes. Testing was undertaken to determine what factors affect the minimum transport velocity. Pipe sizes ranged from 1 to 4 inches in diameter, and suspension concentrations were varied from 0.01 to 0.17 volume fraction solids. Two flow regimes were observed depending on the concentration of the suspension. In the first regime, the suspension was so concentrated as to be in the "compaction zone," and hence had an extremely low settling rate. The second type of flow was observed with more dilute suspensions which were in the "hindered settling zone" and settled 10 to 100 times faster than slurries in compaction. The concentration for transition from one regime to the other was dependent on tube diameter and degree of flocculation. Two different conclusions and settling relationships are given for the minimum transport condition of flocculated suspensions based on concentration. For dilute suspensions, particle transfer owes to Bernoulli forces on the particle and the action of turbulent fluctuations which penetrate the laminar sublayer. For concentrated suspension in compaction, the minimum transport velocity was given by a characteristic critical Reynolds number.

1185 __________. 1962 (Jul). "Transport Characteristics of Suspensions; Part VI: Minimum Transport Velocity for Large Particle Size Suspensions in Round Horizontal Pipes," Journal, AICE, Vol 8, No. 3, pp 373-378.

In Part II of this series, an equation was derived for the "minimum transport conditions" of dilute suspensions of fine flocculated particles. In practical application, particles considerably larger than the 60- to 100-micron range (the upper limit for the previously derived equation) are involved. Therefore, it was desirable to extend the correlation to large size particles and to verify the equation's applicability to nonflocculated particles smaller than the thickness of the laminar sublayer. An empirical-analytical approach again has been adopted. The results of new experiments were combined with prior pneumatic and hydraulic transport data for air and water suspensions to give a unique minimum transport relation valid for particles larger than the thickness of the laminar sublayer. The correlation indicated that the ratio of particle settling velocity to friction velocity at the minimum transport condition is a function of particle Reynolds number, pipe Reynolds number, and the relative density ratio of particle to fluid. Through correlation results, it is apparent that a single mechanism is responsible for the initiation of particle transport over the experimental range of conditions. Furthermore, this mechanism may be identified with Bernoulli forces.

1186 THOMAS, D. G. 1964 (May). "Transport Characteristics of Suspensions; Part IX: Representation of Periodic Phenomena on a Flow Regime Diagram for Dilute Suspension Transport," Journal, AICE, Vol 10, No. 3, pp 303-308.

The object of research reported here is to develop a flow regime diagram for particle transport by combining results from minimum transport correlation (given in previous parts of this series) with new data on sediment wave formation obtained at flow velocities less than the minimum transport condition. Data from other researchers on sediment and particle transport also are incorporated. The resultant flow regime diagram provides a means for describing distribution of particles in a vertical cross section of a horizontal pipe for any given combination of particles and system characteristics. Extensive experimental studies of the flow conditions under which transverse and longitudinal sediment waves occurred showed that all four identified flow regimes for dilute suspensions of solid particles may be represented conveniently on a single diagram in which the terminal-settling velocity divided by the friction velocity and the Reynolds number on particle diameter and friction velocity are the coordinates. Care must be used in applying the flow regime diagram under certain conditions, especially at low flow rates when the sediment layer on pipe bottoms is greater than 0.1 to 0.25 pipe diameters deep. A concentration correction must be applied at the minimum transport condition. Additional theoretical and experimental studies are needed for precisely distinguishing between heterogeneous and homogeneous flows.

1187 TILLOTSON, I. S. 1953 (Jan). "Hydraulic Transportation of Solids," Journal, Mining Congress, Vol 39, No. 1, pp 41-44.

Several phosphate mining operations in Florida, which use hydraulic pumping of the ore matrix, are compared. Initially, the geological formation, geographical distribution, particle sizes, and general mining methods of phosphate are summarized. Overburden must be removed to reach the 10- to 30-foot-thick phosphate beds (unconsolidated material, generally). Draglines deposit the ore into sumps, which then are hydraulically mixed for feeding to a centrifugal suction pump working at various heads depending on terrain and pebble or particle size. Phosphate may be present in occasional 6-inch clumps or as particles fine enough to pass a 400-mesh sieve. The ratio of total solids to water in the hydraulic mixture is the prime factor influencing hydraulic transport; viscosity also is important. Very little research has been done on viscosity, and there is no way to determine with any precision the effect of viscosity on "pumpability." Friction loss plays the major part in making up the imposed head and, consequently, has the greatest bearing on the distance a pumping unit can deliver the mixture. One operation successfully delivers at a distance of 8,000 feet through a 16-inch pipeline, operating at 200 feet pulp head, or 100 pounds per square inch pressure. Solids in suspension do not follow hydraulic theories closely, and unconventional methods must be applied in both the design and application of engineering on these systems.

1188 TODA, M. ET AL. 1969 (Jul). "Hydraulic Conveying of Solids Through Horizontal and Vertical Pipes," International Chemical Engineering, Vol 9, No. 3, pp 553-560.

Experimental results are reported for mixed-phase flow behavior of 0.5- to 3.0-mm particles in horizontal and vertical pipes in the absence of acceleration effects. The velocity profile of fluids also was determined over a wide range of flow states; pressure drop and particle velocity were studied concomitantly. In the case of a vertical pipe, flow state is not so complicated as in a horizontal pipe. The experimental apparatus is described along with measurement methods. Numerous graphs depict typical velocity profiles under various conditions of particle suspension for both vertical and horizontal pipes of several sizes. Results indicate that: (1) the velocity profile of a fluid in horizontal and vertical pipes is affected by flow rate, particle concentration, and other factors; and (2) pressure drop in a horizontal pipe can be expressed as a sum of three terms--(a) pressure drop due to friction between the pipe wall and the water, (b) pressure drop required for allowing particles to be suspended, and (c) pressure drop due to friction between the particles and pipe wall. Two equations have been derived to express pressure drop in a vertical pipe and for expressing the velocity of a single particle in a vertical pipe.

1189 TODD, W. N. 1980 (Oct). "A Solution to Dredge Fuel Problems," Proceedings, World Dredging Conference, WODCON IX, pp 665-683.

Cost of fuel to power dredges is increasing rapidly. As one dredge consultant aptly termed a dredge, it is "simply an animal that you pour in fuel to suck out dirt." This article discusses fuel cost and gives a possible solution: conversion of power plants to burn residual fuels. Three subsections expand the following: economics of burning residual fuels on dredges, engineering and design considerations on a dredge to handle residual fuels, and design considerations of the diesel engine to burn residual fuel. The economics are summarized by two statements: (1) in a good market, dredges running on residual fuels have increased profits; and (2) in a bad market, dredges running on residual fuels will be very competitive against other operators. These statements are backed up by 7 years of data gathered by Pielstick diesel engines. With regard to engineering and design considerations, the major decision is how heavy of a fuel should be selected to burn. Price difference between a #5 heavy and a #6 oil is only 7 cents per gallon. With a system that starts on #2 fuel and switches to a residual upon warming up, if a rapid shutdown becomes necessary (for example, under clogging conditions) and the engine is cooled before being reflushed by #2 fuel, then the injectors, engine fuel lines, and fuel pumps must be removed and cleaned out.

1190 TRAWLE, M. J. 1982 (Apr). "Shoaling Analysis: Procedures for Predicting the Effect of Depth on Dredging Requirements," World Dredging and Marine Construction, Vol 18, No. 4, pp 9-18.

An empirical method of shoaling analysis is presented based on historical shoaling and dredging records. Reliable predictions of future shoaling can be produced for deepened channels, with deepening resulting from increases in authorized depth or advance maintenance dredging. Because of escalating dredging costs, it is important that predictions of shoaling be reliable. Four procedures currently used by the U. S. Army Corps of Engineers for predicting the effect of depth on dredging requirements are presented. The shoaling analysis given here uses the Texas City Channel of Galveston Bay, Texas, as an example. Several assumptions are presented, followed by the example channel description and two phases of the method using regression analysis. A follow-up section describes reduction of dredging frequency while maintaining "controlling depth." Caution is noted in concluding statements that "before any project is evaluated as described in this paper, it should first be determined that the assumptions made will not severely affect the results."

1191 TURNER, H. E. and MCMARTHY, H. E. 1966 (Jul). "A Fundamental Analysis of Slurry Grinding," Journal, AICE, Vol 12, No. 4, pp 784-789.

The need for fine grinding is seen in the demand for fine particle products, reactants, pigments, and other substances. Wet grinding generally produces finer particle sized products than does dry grinding. Although attention has been given to "grindability," little work has been done regarding fundamental definitions of the mechanisms interacting in important types of fine wet grinders and homogenizers available commercially. Three representative slurry grinders or milling devices have been investigated to illustrate the analytical approach; these are the colloid mill, the rod mill, and the high-speed mill. The criterion assessed for mill capabilities is shear force generated as a result of liquid viscosity of the mixture and local velocity gradient in the active grinding zone. Small divergences of slopes for data plotted on log-log paper for the three different mill types indicates a high degree of correlation. This suggests that average particle size of material produced in slurry grinders varies inversely with the two-thirds power of the shear force. The approach and relationships developed will be useful in performance analysis and design of slurry grinding mills.

1192 TURNER, T. M. 1971 (May). "A Significant Inprovement in Dredge Pump Impellers," World Dredging and Marine Construction, Vol 7, No. 6, pp 30-31.

For years, external vanes have been added to impeller shrouds of dredge pumps (between the shroud and head liner) to reduce engine "lugging down" caused by the braking action of sand and other particles in the gap. This article traces several steps of external vane changes on impellers and relates each change to improvement in adverse cavitation and wear effects. Most recently, Ellicott Machine Corporation solved the fundamental problem of cavitation by designing impellers with the external protruding vanes being replaced by recessed "vanes" (actually, depressions in the shrouds) of the same width and approximate shape as

the raised external vanes. The difference between the new and old technique is that there is no trailing surface behind the vane to cause the low pressure cavitation. Conversely, the recessed vane system creates positive pressure. Among advantages of this innovation, now being placed in all new Ellicott pump designs, are the following: (1) the recessed vane is opposite the pumping vane and thus no structural strength is lost; (2) the casing can be narrower and less costly for equal capacity; and (3) the mechanical efficiency of the new impeller is higher because losses due to the braking action are mostly eliminated.

1193 TURNER, T. M. 1971 (Dec). "Optimizing Dredge Operating Conditions," Proceedings, World Dredging Conference, WODCON IV, pp 687-696.

The foremost need of a dredge operator is to know the dredge's instantaneous production rate. Most operators rely on vacuum gauges and operate as close to the cavitation point of the pump as possible, but this ignores the significant parameter of pump speed. Using a new test facility containing a "closed-loop" dredging system with cutterhead, diesel-driven pump, and extensive instrumentation, the Ellicott Machine Corporation has invented the "Solids Optimizer" to detect peak instantaneous solids content for operator visualization. The device's operating principle is sensing of pressure differences in two moving columns of slurry. The device uses two lengths of pipe exactly the same and, because the velocity and friction drop in each pipe section is the same, the readout is an accurate indication of specific gravity. For the "normal" dredging operation, 45 percent peak volume (specific gravity 1.5) is close to optimum. Disadvantages of the radiation method, the weight sensing method, and the sonic method are explained. The "Solids Optimizer" can help alleviate environmental disturbance by maximizing dredge output to reduce job time and by reducing cutter speed--and thus turbidity--while maintaining a high solids suction rate.

1194 __________. 1975 (Mar). "Submerged Dredge Pumps Increase in Acceptance," World Dredging and Marine Construction, Vol 11, No. 4, pp 35-37.

Larger dredges built in the future will be equipped with submerged dredge pumps, and many existing dredges will be rebuilt to receive them. Submerged pumps preclude cavitation problems and allow good production at greater depths. Depth requirements have increased because of the construction of very large, deep-draft vessels, deep ocean mining, and the need to use existing borrow pits at depths from 40 to 100 feet. Tests show that a submerged pump can more than double the maximum output of a dredge at a 50-foot digging depth and quadruple it at an 82-foot digging depth. Submerged pumps eliminate the need for gas removal systems in the pipeline. The advantages of submerged pumps are described relative to production, cavitation, power requirements, and electrical drive versus hydraulic drive. Ellicott Machine Corporation devised the first submerged electric drive, and this development is discussed. With regard to economics, the "first cost" of the submerged electric drive is roughly 10 to 20 percent higher than the equivalent hydraulically driven unit.

V

1195 VALLENTINE, H. R. 1955 (Apr). "Transportation of Solids in Pipelines," Commonwealth Engineer, pp 349-354.

Much thought and work has gone into studying the hydraulic "dredging problem," that is, the use of water flowing in pipes as a transporting medium. On the other hand, little consideration has been given to the "drainage problem," in which unwanted sediment becomes deposited in significant amounts in pipelines. Experiments conducted at the Iowa State University of Hydraulic Research are reported. Sand was transported as bed load in 6-inch-diameter plastic pipe under two conditions: (1) free-surface pipe flow with a sand bed-load but without a deposited bed, and (2) pipe flow under pressure with a sand bed-load and with a deposited bed. For the first condition it was found that a uniform sand bed-load results in a slight increase in flow depth and a marked increase in the mean resistance coefficient; measurements were made every 5 feet along 30 feet of pipe. For the second case, the piezometric gradient lies within a certain range, the lower limit of which corresponds to clear water flow. Experiments with nonuniform sands yield results similar to those for uniform sands. Sample calculations and graphs are provided for assisting in drainage system designs.

1196 VALLENTINE, H. R. and WOOD, I. R. 1963 (Feb). "Hydraulic Transportation of Ash in Pipes," Interim Report submitted to Electricity Commission of New South Wales.

This report is one part of a series of hydraulic studies performed at the Water Research Laboratory at The University of New South Wales. In new power plant designs, it is proposed to move fly ash by mixing it with water and pumping it considerable distances. To design an economical system, the minimum velocity of ash transport without settling and the head losses in pipes must be computed. The investigations thus far include determining the properties of ash-water suspensions of various "gradings" (particle sizes) and concentrations, the minimum velocities at which no deposition occurs, and the losses in 4-inch and 6-inch pipes. Critical settling velocities were found to decrease with higher concentrations, but increase with the presence of coarser particles. At 40 percent concentration, critical velocity in a 6-inch pipe was 4.5 feet per second, and in a 4-inch pipe, about 2 feet per second. Head loss estimates were determined for particles ranging in mean size from 30 to 70 microns, and for concentrations (by weight) of from 20 to 50 percent. The effect of deposition of ash from suspension in the event of pump shutdown also was investigated. It was found that pumping could be resumed normally provided that water was maintained in the line. Additional experiments are being prepared for studies on another type of ash and on pumping head required to clear ash blockages.

1197 VAN BAARDEWIJK, A. P. H. 1968. "The Influence of the Conditions of Soil on the Dredging Output," Proceedings, World Dredging Conference, WODCON II, pp 465-485.

After a brief introduction to past limitations of the dredging industry, most of the article considers the variability of many environmental aspects encountered in dredging and methods by which the industry has improved. Emphasis is placed primarily on "soils," which include virtually any naturally occurring dredges material. It is pointed out that, as opposed to other industries, the dredging machinery must handle a variety of products (soils) with varying characteristics and often occurring simultaneously. Thus, adaptability has been a necessity in dealing with soil types, weather conditions and working conditions. Scientific analyses of soils often were given too little emphasis on projects prior to when dredging was to begin, but more recently, direct measurements of the soil mass or obtaining representative samples have improved. As a result, especially in the last few years, the knowledge of factors important to dredging production has been extended considerably. The means of action on soil of a variety of dredge types is discussed. The article concludes by carefully defining six soil types and discussing characteristic interactions between the dredge and the soil. The six types discussed are sand, silt, clay, peat, gravel, and rock. Site specific tests are recommended for any project.

1198 VAN DORST, J. C. and VAN OOSTRUM, H. A. 1980 (Oct). "Automation as a Manager's Tool," Proceedings, World Dredging Conference, WODCON IX, pp 205-216.

Microelectronics is playing an increasingly important role in the dredging industry. Automated programs may be employed both toward the goal of raising the productivity potential and toward reducing the price per unit of production. This paper presents a viewpoint on how computer-based systems can be applied as a support for the management of dredging works such that man and machine can both be employed to the best of their abilities. In general, this means that the computer supplies information necessary to make "arguable decisions." Achievements in using such systems include increased quality control (with respect to "necessary" production), cost reduction through increased efficiency, better management support with reliable data, and an increase in a contractor's efforts to improve on his "working stock and methods " Major report sections explain the definition of the dredging system in data-handling terminology; the computer-based subsystems (shore-based or on-board); fixed information and real-time information; and process interpretation, feedback, and evaluation subsystems. Development of an operating system is traced in the final segment of this report. It is noted that other industrial branches are far ahead of dredging in the field of computerization.

1199 VAN DYKE, H. J. 1982 (Aug). "Contract Dredging Step by Step," World Dredging and Marine Construction, Vol 18, No. 8, pp 6-11.

Of all contracts written in the construction industries, those for dredging may be the most difficult to formulate. Successful dredging projects must start with proper understanding and agreement on objectives between the parties, followed by proper preparation and sequencing

of contract procedures. Thus, once a contractor is on site, there is no doubt about the work to carry out and the process to use. This article provides numerous proven contract writing techniques, bidding and contractor selection methods, and suggestions for work inspection and claims settlement. Fixed price, cost reimbursable, and equipment leasing type contracts are described. Selection procedures are discussed based on the assumption that matching the dredging plant to the work is of primary importance. Other topics covered include field investigations, soils classifications, tender documents, general and special contract provisions, scope of work requirements, type of measurement for pay, engineering reporting and site preparation.

1200 VAN HAAREN, J. P. 1972. "A New Generation of Mineral Dredgers," Ports and Dredging, No. 73, pp 4-8.

IHC Holland has worked with the mining industry for a long time; the oldest IHC equipment still in service dates to 1914. Much of the equipment built by IHC has been for the large tin mining/dredging industry in Malaya and Thailand. Several new developments have recently improved the tin mining efficiency at greater depths. A new type of ore treatment jig is a most important development. The specific problems of a tin ore bucket dredger and solutions which justify the title of a "new generation" are reviewed. The new drive system for the jig and the jig itself gives advantages in the layout of the entire ore treatment plant and increases efficiency when dealing with finer materials. Operations of the new equipment and comparisons with previous problems are described. Output of a treatment plant may be viewed as a function of the product of the bucket speed and bucket capacity. Maximum output is discussed in these terms and considering working depth and bucket construction. Problems of dredging in a "tin mining pond" are explained, especially with regard to spillage and tailings disposal, and the use of the new equipment for improving overall efficiency. It is noted that, based on 600 working hours per month while recovering 800,000 cubic yards (output), 10 of the recently designed jigs can do the work of 90 jigs of a conventional type. Subsequent articles will deal with other novel design features of mining bucket dredgers.

1201 VAN HEIJST, W. S. "Pipelaying Under Water, Embedding Pipelines in a Sandy Bed by Means of Water Jets," Oil Report No. 9, IHC Holland, pp 6-9.

Embedding underwater pipelines by dredging is a common but expensive method, and there is need for a simple and inexpensive technique. The answer is using water jets in sandy beds. The Mineral Technology Institute (MTI) of IHC Holland developed a system which uses water jets to bury a line. The aims of extensive studies by MTI included determining optimum physical and technical characteristics of a trenching unit and studying the interactions among the unit, the pipeline, and the soil to arrive at an optimum operating procedure. The method of pipelaying chosen for testing was that of laying the pipe first and then cutting a trench beneath it. The trenching unit developed is a saddle-like

me with pipe guide rollers, a stabilizing tank, and jet nozzles and ociated equipment. For a given type of sand, the cavity depth was ınd to depend on water pressure and flow rate. It also was discovered t for a given jet power, a high flow rate at low pressure produces a per cavity than a low flow rate at high pressure. Low towing speed o is most suitable. Towing speed to bury a 1.6-meter-diameter pipe meter deep is about 0.5 knots. Repeated tows can bury a pipe to ce its diameter beneath the sand.

2 VAN LOHUIZEN, H. P. S. 1968 (Oct). "Economic Considerations for Sand Acquisition and Applied Methods of Winning for the Purpose of the Reclamation of Industrial Sites," Proceedings, World Dredging Conference, WODCON II, pp 623-637.

The means of reaching Amsterdam's port facilities are traced from time of approaching the city from the east via the Zuyder Zee, ough 1877 when the first "dock grounds" were constructed, and until building of the Noordhollands Canal and finally, the North Sea Canal nnected by the Ymuiden Locks to the North Sea). Recent port extenns and anticipated future extensions west of the city require enors amounts of sand to construct dock facilities built up above sea el. Most of this article discusses the means by which such huge unts of sand are retrieved from the North Sea (the Sea Sand Project). general system consists of first dredging the sand by suction hopper dges, depositing it at a "buffer pit" near but outside the locks, n pumping it hydraulically into barge-loading silos beyond the locks the east. In the silos, salt water is removed by flushing from below h fresh water and pumping the salt water back to the North Sea. The ıid 50-50 sand-water mixture then is emptied from silos directly into ge-capacity (1800 cubic meters) barges for pushing to the reclamation a.

3 VAN LUNDEREN, P. J. 1968 (Oct). "Dredge Builders News on the Design and Construction of Dredging Equipment," Proceedings, World Dredging Conference, WODCON II, pp 677-697.

This article consists of a dialogue between an operator and a lder of trailing suction dredgers; the subjects covered vary, but nly concern economic aspects. Among the topics dealt with in most ail are rapid general development trends both in the need for large dgers and the dredgers themselves, hopper filling, suction pipes, ntenance, dredge equipment layout, diesel and diesel-electric drive tems, material dumping methods, crew costs, construction costs, autoion, and standardization. There are still a great number of problems be solved, but operators and builders working closely together will ıd the best solutions.

4 VAN OOSTRUM, W. H. A. ET AL. 1980 (Oct). "Marketing in Dredging, A Principal's Vision," Proceedings, World Dredging Conference, WODCON IX, pp 59-74.

A study carried out by the Port of Rotterdam and Rijkswaterstaat ween 1976 and 1980 on the relation between "buyers" and "sellers" in dredging market is discussed. The world's top 20 dredging nations listed. It is noted that with regard to capacity, 40 percent of the ld dredging fleet is "state owned," leaving 60 percent held by prie firms. Buyers (or contractors) generally aim for continuity of k and maximization of sales and profits; to do this, a company must keep customers satisfied, (2) build his market, and (3) keep abreast the potential effects of political and social changes on future comy policy. The general aims of the clients (the "sellers") include ntaining the depth of a navigable waterway and keeping expenses to a imum. A company that knows precisely what is or is not satisfying to tomers also knows where to concentrate its resources and efforts on roving efficiency. Results of this comprehensive study have led to a e balanced capacity allocation distinguished for capital and maintece dredging; basic, seasonal, and peak capacity; and special equipt related to specific conditions.

5 VAN VEEN, J. 1962. "Dredge, Drain, Reclaim, The Art of a Nation," Fifth Ed., Drukkerij Trio, The Hague.

The story is told of Holland--The Netherlands--and its continuing tle against being inundated by the Sea. Originally written during years of World War II, the book now has chapters added since the ods of 1953. Although some numerical data and a large number of rts, photographs, and maps accompany the report, this story is writmuch more from a historical than a technical viewpoint. Holland is ically a delta of sand and soft materials deposited upon the final reat of the ice age. Large, wide, slow-flowing rivers continued to ng sediment into the area, and the sea tides also daily transformed soft deposits. Earlier men hunted in or sailed near the land, but one dared to live there. The first inhabitants (farmers) settled on ch soil about 4000 B.C. according to archaeological investigations. se people, who probably came from Scandinavia, were known as Frins, and lived only in the northern part of the land. The ancient ans recorded their presence. They built the first artificial high as to keep above the waters; these heights (as mud mounds) still st. This earlier "spade work" and other endeavors carried out well o the sixteenth century are covered in the first chapter. Three adional chapters continue the story of reclaiming, the beginning of omation, building dredgers and canals, the great Dutch floods, and "Delta Plan." A look to the future also is given.

6 VAUGHN, R. L. 1940 (Feb). "More Profit from Suction Dredges," <u>Engineering New Record,</u> Vol 124, No. 9, pp 52-54.

Practical suggestions and their applications are given for effint operations of suction dredges and transporting pipelines. For any en mixture to be dredged in an efficient manner, the weight of mixture ped should fall within narrow and well-defined limits. It is shown t energy put into the pipeline must equal that expended; six types

ta are needed for this computation: (1) loss of head, (2) weight terial dredged, (3) suction lift, (4) static lift above pump, ower put into pipeline, and (6) rate at which material is moved. of these subjects is further discussed. Economy of operation is ubject of a brief concluding discussion.

VELTER, G., BONNIN, O., and KUHLMANN, L. 1980 (Oct). "DALI-S, A New Versatile Tool for the Supervision of Marine Construction and for Hydrographic Surveys at the Port of Sete," Proceedings, World Dredging Conference, WODCON IX, pp 251-269.

DALI-S is a computer program developed by the French Lighthouse rity. It is used in conjunction with a radio-positioning system, th sounder/recorder system, and a data acquisition/processing sys- o supervise port construction and survey activities. The compo- and operations of the system are described, as well as the theo- al philosophy of the computer program's approach to representing m contours. In 1979 United States dollars, the total system cost 375,000; this represented 1.2 percent of the cost of civil works cts in progress. Use of this type of system will be expanded to French ports because satisfactory results have been achieved.

VELTMAN, M. 1980 (Sep). "Dutch Study Project Seeks Data on Maintenance Dredging Methods and Cost," World Dredging and Marine Construction, Vol 16, No. 9, pp 12-19.

A Dutch study organization represented by several public groups tempting to understand the "laws of nature at the root of the phe- ion of sedimentation in the Port of Rotterdam," and consequently to measures to reduce maintenance dredging. A "marketing group" is ing dredge equipment in search of ways to reduce expenditures. The mation presented here concerns fourteen working groups that are ing sedimentation problems. Among the topics elaborated upon are nded ("floating") particles, sediment consolidation, data acquisi- and processing, echo sounding, and silt screening to prevent harbor entation. A "clay sales group" is trying to find useful purposes ll the clay sediment being dumped ashore. Dutch farmers cannot use aterial because of the pollutants contained in it. Disposal within diked areas built above sea level may be possible; research is nuing on this and other disposal techniques.

VICK, H. R. 1974 (Nov). "Maintenance Dredging in the New Orleans District, U. S. Army Corps of Engineers," Proceedings, Seventh Dredging Seminar, Texas A&M University Center for Dredging Studies, Report CDS-181, TAMU-SG-76-105, pp 79-110.

This article gives a general overview of the size and extent of lew Orleans District, U. S. Army Corps of Engineers, and describes enance dredging equipment and operations throughout the District. esent, 42 navigation projects and 2,800 miles of navigable water- must be kept operating. About 405 miles of the 2,800 are deep- waterways. Annual maintenance dredging includes 110 miles of

a decrease in the frequency ratio, or an increase in the end load ers, all increase the range of dynamic stability in space. Nu- examples illustrate that practical dredge pipes for depths of feet can be designed which are safely distant from stability ies.

WISLICENUS, G. F., WATSON, R. M., and KARASSIK, I. J. 1939 (Jan). "Cavitation Characteristics of Centrifugal Pumps Described by Similarity Considerations," Transactions, American Society of Mechanical Engineers, Vol 61, pp 17-24.

Work described was carried out at the Hydraulic Laboratory of the litan Water District of Southern California and at the California te of Technology. The initial problem was to work out a method dinating the results of cavitation tests on centrifugal pumps to obtained at different speeds on the same pump. It was solved by g the Thoma-Moodt "similarity law" for the cavitation performance aulic pumps and turbines. Pertinent detailed definitions are d, followed by derivations of parameters allowing extension of avitation test results to other pumps and/or operating condi- A new parameter S is derived which, at moderate and low speeds, nearly independent of a pump's specific speed. Several examples lications of the derivation are given involving "factoring" (that nging all dimensions of a new pump by a constant) or changing rpm ments while still maintaining a certain output against a given

WOODBURY, C. E. 1968 (Oct). "The Transportable Hydraulic Cutterhead Pipeline Dredge," Proceedings, World Dredging Conference, WODCON II, pp 735-770.

Portable hydraulic dredges are becoming more popular because they only a modest investment relative to production capability. rrent owners of these dredges have had little or no dredging ex- e, and it is the purpose of this paper to make owners aware of tfalls and demonstrate how they may be avoided. Today it is e to produce portable dredges of about 20-inch size, which will equally as well as the nonportable types. Portable dredge de- s one overshadowing influence in all considerations, and that is (distributed where it functions best). Some of the best design ions on the portable dredges include forward mounted underwater drives and swing drums mounted on the ladder at the trunnion end. omponents of the portable dredge are discussed with respect to attributes for portability and efficiency; among these components ull, superstructure, deckhouse, power plant (including gas tur- gines), pump, hoist, cutter machinery, hoist and cutter drives, ar, rigging, and pipeline. Although the portable dredge has many ges, it probably has the highest maintenance cost to first cost f any piece of contractor's equipment.

A new approach to decision making applicable to the dredging in-
y is outlined. The approach involves using the "total imagination"
n the framework of "balanced risk decisions." One person today
t know enough facts and their treatment to make optimum decisions
mplicated projects; therefore, we must always suppose there are
and possibilities not yet in and create some acceptable level of
in making decisions. This approach is good for long-term benefits
ot applicable to the short-term quick gamble because considerable
of known facts must be involved. By knowing risks, one can rap-
judge whether or not to proceed with an operation. Six basic parts
ved with decision making in the dredging industry are discussed:
es or goals of the persons involved, parameters within the dredging
m, methods of reasoning, tools of reasoning, basic means for ob-
ng goals, and risk outcomes. Deductive and inductive reasoning are
ined. Among the types of decisions encountered are: (1) whether
t to rehabilitate existing equipment, (2) how to optimize design
ity, (3) what use of monitoring should be made, and (4) how should
ance coverage be calculated.

WILLMOTT, L. F., HUFF, W. R., and CROCKETT, W. E. 1962. "Aqueous Slurries of Coal and Granular Materials, A Bibliography," Circular 8165, U. S. Department of the Interior, Bureau of Mines.

On a pilot plant scale, the U. S. Bureau of Mines has been inves-
ing methods of gasifying coal with oxygen and superheated steam to
ice synthetic gas. One method of process feeding the coal could in-
a continuous coal-water slurry system. Before developmental work
, an extensive literature search into the technology of aqueous
ies was conducted to establish design criteria. This bibliography
sents a compilation of collected literature. A total of 349 pub-
ions are listed in 102 journals published worldwide.

WILSON, J. F. and BIGGERS, S. B. 1974 (Nov). "Responses of Submerged, Inclined Pipelines Conveying Mass," Journal, Engineering for Industry, Vol 96, No. 4, pp 1141-1146.

The classic study of bending vibrations in pipes conveying fluids
lone in the early 1950's, with subsequent studies performed for an
ned (but initially straight and empty) dredge pipe under constant
load. The investigations described here involve an inclined sub-
d pipeline which is allowed to have an initial static deflection
caused by transverse fluid drag forces, added deadweight, and a
rly varying load arising from self-weight. The pipeline is mod-
l as a Bernoulli-Euler beam. Pipeline stability and transient re-
es are determined for a constant flow rate suddenly imposed on the
ined fluid mass. Applications to dredging are discussed because
nformation is applicable to conveying mineral deposits to ships
the ocean floor. Data also are useful for the design of oil pipe-
. The present study reveals that five dimensionless parameters
n dynamic stability and dynamic response conveyed to an inclined
line. With other parameters held constant, a decrease in the mass

Shortly before World War I, construction began on excavation of New Orleans Inner-Harbor Navigation Canal, which connects the Mis- ippi River to Lake Pontchartrain. Some of the outstanding engineer- features incident to the completion of that dredging project are ented. The length of the canal is 31,800 feet, with a clear channel h of 150 feet, and a depth of 30 feet. Because dredged material was ıe used to reclaim certain areas or build dikes, cutter-suction pipe- dredgers were necessary rather than grabs. Five dredgers were ıght in, some from as far as Cuba. The largest was the 22-inch :as." The very unusual character of the material presented a prob- although the soil was soft, it was densely intermingled with roots large cypress stumps. Because of the high percentage of areas with .e roots/stumps, pump impellers and passages were redesigned to re- clogging and increase output. Test data for four of the five rede- ıed dredges are presented in tabular form. After making changes in pumps, output increased by 200 to 300 percent, and costs definitely justified. In one instance, the normal impeller rotation was re- ,ed for a 2-week period to observe performance. No change in output noted, but there was a 10 percent loss of efficiency from increased :r consumption.

WIENDIECK, K. W. and FREITAG, D. R. 1970 (Dec). "The Role of Ground Crawling Vehilcles in the Ocean," Civil Engineering in the Oceans II, pp 327-347.

Successful use of the seafloor is likely to be a major asset in conquest of the oceans. Machines and techniques for transport on two-dimensional surface must be different from those used in the :e-dimensional ocean. Seafloor crawling vehicles are ignored mostly :he literature, but the need for a variety of these machines is eas- foreseen. An attempt is made here to review operational areas of ı vehicles, and to indicate the direction of research in predicting .r performance. The history of early seafloor crawling vehicles is :ed from the earliest "Argonaut, Jr.," built in 1894, through those :loped by Bell Telephone Laboratories in the 1960's. Seven specific ıines are described including the Bell Sea Plow, the Harmstorf Sled, Anderson Undersea Crawler, the Tracked Diving Bell, and the British ry-Duty Sea Bed Work Vehicle. An analysis of locomotion is made com- .ng applications on land to the requirements of seafloor transport. "soft-soil mobility problem" also is examined from the standpoint of .-vehicle machanics. Running gear configurations and requirements considered, especially with regard to the parameters of "slip" and .1." Possible vehicle concepts are numerous, but the basic available ıing gears are few; in historical order these are: sled, roller, :1, chain, track, screw, and let types. The most relevant features ı seafloor mobility scheme are given.

WIGGINS, J. H. 1972 (Aug). "Practical Profit, Security and Safety Goals, Balanced Risk Approach to Dredging," World Dredging and Marine Construction, Vol 8, No. 9, pp 12-15.

veral pages of this article are devoted to examining the components of e survey sweep beginning at the most baisc and going through the most phisticated configuration.

30 WERENSKIOLD, K. 1973 (Nov). "Rock Dredging Described in Norway," World Dredging and Marine Construction, Vol 9, No. 13, pp 24-27.

Dredging activities are described for drilling, blasting, and moving 250,000 cubic meters of solid rock, and for dredging 400,000 bic meters of broken rock and overburden in the River Glomma, Norway's rgest river. Because of extensive flooding caused by natural blockage the river immediately downstream of shallow Lake Oyeren, model tests re undertaken to ascertain a solution to the problem. Tow factors olved that had to be rectified: (1) gain hydraulic head for more pid drainage by increasing the cross section of the river gorge from average depth of minus 7 meters to minus 11 meters; and (2) clean up e river bottom and make it more streamlined to reduce water friction. do this work, 300 meters of the river from Lake Oyeren downstream had be blasted and dredged. Because of solid freezing conditions on the ke in mid-December, and because the contract was signed in September, l equipment had to be designed, built, and transported in before eeze-up. Working period is October 1 through winter until April 1 en high runoff and water levels cease all work. Equipment was prered on time and relatively few problems were encountered. Dredging gan on December 10; steady payable production is expected the first y of the next season.

31 WHEELER, B. A. 1980 (Nov). "ARC Marine Expanding in Lucrative U. K. Offshore Aggregate Market," World Dredging and Marine Construction, Vol 16, No. 11, pp 21-24.

A. R. C. Marine Limited was formed in April 1968 as Amey Marine mited; combined were five companies with considerable experience in rine aggregate dredging around the U. K. coast. Initial year producon was 1.3 million tons. Production per year now is approaching 4 milon tons. With land gravel reserves in England declining, marine operors should continue to get a larger share of the market, and also can pand to other areas. This article describes in detail the activities volved in establishing A. R. C. Marine Limited, and gives the locaons where operations are carried out. All ships ordered for suction pper dredging were built by Appledore Shipbuilders; several of these e pictured and discussed. A. R. C. Marine is continuing to develop chniques and hardware to ensure its leading position in the home mart and to become established in Australia and the United States in the 80's.

32 WHITE, W. J. 1920. "A Dredging Pump of Novel Construction," Journal, American Society of Mechanical Engineers, Vol 42, No. 1, p 80.

are important for good discharge, requiring entirely smooth hopper construction. A mixing chamber was incorporated into the hopper design. For fluidizing solids, water could then be fed from the bottom and surface. Particularly good results were achieved by adding water over as large an area as possible (at top or bottom). If water is being added, unloading time cannot be reduced by optionally adding greater quantities of water. The new procedure resulted in peak sand transport concentrations of 78 percent and mean values of 55 percent. A full-scale test on a dredge confirmed the findings, but a mean of 45 percent concentration was achieved in the field test.

1228 WELTMAN, R. N. and KUHNS, P. W. 1955 (Aug). "An Automatic Viscometer for Non-Newtonian Materials," Technical Note 3510, National Advisory Committee for Aeronautics.

The transfer behavior of fuels and lubricants when passed through an aircraft propulsion system is controlled by the flow properties of these fluids. An instrument was designed to measure the non-Newtonian flow parameters of such aircraft fluids; this apparatus (viscometer) is described herein. The viscometer was designed to meet six criteria regarding shear rates of the materials, end effects, and temperature increases due to shear. Viscometer construction is explained. Final design is a concentric-cylinder rotational viscometer that can measure viscosities in the range of 0.05 to 20,000 poises. It can also program and record flow curves of rate of shear versus shearing stress for most non-Newtonian materials, record time-torque curves, and produce dynamic flow measurements. A programming feature allows selection of: (1) shear rate up to 4000/second, (2) the time of increasing rotational speed from zero to a preset maximum, and (3) two sequences of rate of shear (varied automatically at a constant acceleration). Test data and curves are presented.

1229 WENTZELL, H. F. 1982 (May). "Sweeping Survey System Improves Dredging Efficiency, Increases Traffic Safety," World Dredging and Marine Construction, Vol 18, No. 5, pp 21-25.

The Atlas Boma 20 is an electronic bottom sweeping system suitable for waterway safety surveillance or for hydrographic surveying. The various outputs from this type system show bottom contours more clearly than do cross profile survey plots. In European waterways, these systems are in common use and are contributing to the safety of many harbors and inshore areas. Recent developments in position determination technology make these systems ideal for economic hydrographic surveying when accuracy to within 3 feet is needed. One of the main advantages of these bottom sweeping systems is that they provide "gapless" coverage. When the ultrasonic transducers are mounted on two 60-foot-long booms on a 30-foot-wide survey vessel, a sweeping path of 150 feet can be made. The booms horizontally stabilize the vessel, but cross-current surveying is not possible. Transducers on vessels to be used for surveying along or across the long axis of an area can be mounted on a special support bar at the water level or on the keel.

includes the contraction device, radiation detector, and pneumatic device. Combined measurement tools are the loop system and certain electrical systems which combine a magnetic flow meter with a radiation detector for density measurement. It is concluded that even though numerous measuring devices have been reported in the literature, their uses and scope of application have been quite limited. Some of the methods reported here are inaccurate; others can be used confidently in cases where high degrees of accuracy are not needed, such as on dredging operations. Other devices need to be developed and tested.

1226 WELTE, A. 1970. "Hydro-Jet Deep Embedment Method," Proceedings, World Dredging Conference, WODCON III, pp 273-292.

A method of deeply embedding electric cables and plastic or steel pipes in marine soils is described. Rudolf Harmstorf developed the method over 30 years ago, and has been improving it ever since. Hydrojet units suspend the bottom sand/soil resulting in a trench; the cable or pipe immediately is deposited and is then rapidly covered ("flushed-in") by sand. Depending on the depth of water, three different types of machines are employed; a laying vessel in deep waters, a pontoon vessel in shallow water, and a sledge-type crawler tractor in extremely flat or extremely deep waters. Cables or pipes to be layed by the hydrojet unit are supplied on a reel; they are fed into the trench taking the minimum bend radius into account. The speed of the flushing-in process varies with depth of water, width of the ditch, and nature of soil. Where heavy, solidifying, or binding soils are encountered, the action of the water jets can be supported by mechanical vibrators rigidly fitted to the upper end of the hydroinjector. To date, the largest plastic pipes embedded had a diameter of 630 mm, but a large hydrojet unit on crawler wheels is being prepared to embed plastic pipes with diameter of 1200 mm. This machine will be able to work in water 50 m deep and provide a maximum flushing depth of 5.5 meters. The hydrojet systems can simultaneously lay several cables or small pipes.

1227 ________. 1975 (May). "New Processes Provided for Unloading Hopper Dredges," World Dredging and Marine Construction, Vol 11, No. 6, pp 54-58.

Self-propelled hopper suction dredges plan a major role in channel maintenance, and they are capable of taking on board firmly compacted soils. These dredges can either dump using bottom doors or pump ashore through pipelines. Dumping takes only 6 to 12 minutes, but pumping may require 2 hours. Where pumping is necessitated, reducing the time would enhance economic profitability. Six disadvantages of pumping ashore are described. A new method to improve "pumpability" is the use of "flushing water" provided at the surface of the sand in the hopper. A model test first was performed using a hopper at a scale of 1:10 for length, breadth, and depth. During tests, several factors were varied. Measurements were made as functions of time. Most noteworthy of results is that, with addition of flushing water, it was possible to greatly improve discharge of solids. Design and form of the hopper also

Pre- and postdredging hydrographic surveys on the Mississippi River are discussed from the viewpoint of reducing errors in calculating material quantities. Reduction in errors is gained through the use of automated methods and computerized data analysis. Accuracy in obtaining correct dredging quantities can mean savings of millions of dollars in dredging costs for only one foot of depth dredged. The application of the Hydrocarta System is described for the dredging surveys used as examples. Four major groups of errors are possible: depth-related errors, position-related errors, errors due to lack of synchronization of events, and integration errors in computer analysis. Depth-related errors often are in the form of false echoes being included by the computer in automated systems. A method is shown for eliminating these errors. Sea and swell are the largest sources of depth error; "heave sensors" now are becoming available to eliminate this error source. Position-related errors include invalid range signals, errors in assuming a "flat earth" on an extensive project, and errors from sinuous survey lines. A computer program must only use the component of travel parallel to the cross section being evaluated. With a shipboard computer, cross sections are computed and drawn daily on site; this permits more precise control, which means less unnecessary dredging and therefore a reduction in cost.

1224 WEISMAN, J. 1963 (Jan). "Minimum Power Requirements for Slurry Transport," Journal, AICE, Vol 9, No. 1, pp 134-138.

An equation is derived which predicts minimum power requirements to maintain nonflocculated particles in suspension in an aqueous slurry. A large set of data from various authors have been correlated using the equation. Examination of these experimental data indicates that minimum transport power varies with the square root of the ratio of pipe diameter to average particle diameter. Wide ranges of conditions, particle sizes, and material types were included among the correlated data. Materials included sand, glass, lead, steel, tungsten, and barium sulfate. The successful correlation of the data appears to justify the original assumption that the mechanism for particle suspension in pipes is similar to that in mechanical mixers. At power levels below those predicted by the equation, portions of slurry will remain stationary on the bottom. Care should be used when applying the equation to very dilute suspensions because, for an infinitely dilute suspension, the equation would predict zero power requirements.

1225 WEISMAN, R. N. and GRAF, W. H. 1968 (Nov). "Measuring Solid-Liquid Mixture in Closed Conduits," Journal, Waterways and Harbors Division, ASCE, Vol 94, No. WW4, pp 453-464.

Several methods or devices are described which have been used for measuring two basic quantities associated with mixture flow: flow rate and solids concentration. Applications, advantages, problems, and limitations of each method are reviewed. Those methods which measure flow rate include the brine injection method, the trajectory method, and the whistle meter. Equipment designed for measuring solids concentration

remedial measure that is tolerated and is more or less continuous. Its purpose is to optimize a port's commercial activity, but dredging cannot be divorced from the rest of the activity. Dredger specifications presently are derived by using long-term dredging requirements and long-term output of the projected dredger. A safety factor provides for emergencies. The equation representing this situation is a static model of a dynamic system. It is shown that this steady-state equation can only represent the system in a "noncritical state," that is, only when the system does not require emergency measures to keep operative. Any new method must encompass the following: (1) minimize errors inherent in use of historical data, (2) deal with combinations of dredgers, (3) assess performance in critical periods, and (4) provide cost/benefit information in a suitable form. The new model proposed meets these criteria in predicting dredge performance and uses historical actual case data. Stepwise operation of the model is shown. Computerization allows producing data on many combinations of dredgers and systems. The validity of the model (for examples given) is assessed by comparing simulated with actual results. In conclusion it is noted that the model appears reliable, that validity depends on the reality of assumptions made, and that its main strength is that it deals with dredging as a dynamic operation.

1222 WEBB, R. J. 1974. "Dredging Costs, Their Estimation and Implications to the Management of Maintenance Dredging Operations," Dock and Harbour Authority, Vol 2, pp 406-409.

The real output of maintenance dredging normally is fixed by the physical conditions existing in a port. If efficiency is measured by output/cost, it can be increased only by reducing the cost of realizing the same output. Costs must therefore be established with confidence in any costing exercise of a business operation. Of course, items of cost not affected by changes in the dredging system (that is, costs outside the engineer's control) can safely be ignored. Much of any costing exercise is subjective. Herein, three costing systems are compared based on one year's data from operation of a dredger built in 1967 and operating in 1970-1971. The three costing systems are: (1) traditional financial accounting, (2) the NIVAG costing model, and (3) opportunity costing. Each system considers various costing aspects such as depreciation, interest, inflation, operating costs, capital costs, and maintenance. The first two costing systems come from industry. Opportunity costing is designed to quantify the advantages foregone by a port authority in order to discharge its dredging commitments; this is achieved by comparing options at year's end to those at the start of the year. In summary, financial accounting underestimates the cost of operating a dredger. Also, research should be directed toward minimizing capital involvement rather than toward overtime limitation or fuel economy.

1223 WEEKS, C. G. and STEPHENSON, A. G. 1979 (Mar). "The Errors of Dredge Quantity Calculation and a Way to Reduce Them," World Dredging and Marine Construction, Vol 15, No. 3, pp 10-15.

1219 WATANABE, R. 1970 "Utilization of the P.B.L.S. (Pusher Barge Line System) in Reclamation Projects," Proceedings, World Dredging Conference, WODCON III, pp 379-400.

In Japan, coastal land reclamation and harbor construction projects are becoming greater in scale. Even though surrounded by the sea, suitable sites are limited, and fill material must often be moved long distances. This article describes development of a large-scale sand transport operation using a pusher barge line system with several times the capacity of those in common use. The 7-year project for which the developments have taken place involves shortening an inland sea canal by removal of two large sandbars and moving the material about 150 km to reclaim a site in Osaka. Initially, 1.5 million cubic meters per year are being moved, but capacity will soon be doubled. Special techniques are discussed for handling larger barges (6,000 cubic meters), greater loading rates, faster transport with larger pushers between loading and unloading points, and unique mooring systems for safety. Unloading of barges is by suction with booster pumps. One barge trip cycle for this project requires about 43 hours; pusher time is 21.4 hours. Even though only 5 months of the project have elapsed, good progress has been made, and the fleet of sand carriers soon will be enlarged.

1220 WATSON, R. M. 1947 (Oct). "Cavitation in Centrifugal Pumps, Some of the Less Well-Known Factors," Proceedings, National Conference on Industrial Hydraulics, Vol 1, pp 50-65.

Cavitation in centrifugal pumps has been a concern to manufacturers and users alike; it causes erosion of pump elements, excessive noise, and unstable performance. Cavitation generally is considered undesirable, but this is not necessarily the case as shown in several situations here. General operational principles of several types of pump design and the cause of cavitation are explained. The head required to prevent cavitation is mathematically derived. "Suction specific speed" is discussed in relation to pump capacity (gallons per minute) and head. For normal commercial purposes in pumping cold water or single-component liquids, the suction specific speed is limited to 9,000 to avoid all cavitation, including that due to surface abnormalities, departure from desired shapes, and so forth. However, two types of service involve conditions permitting higher suction specific speeds: (1) condensate service in steam power plants, and (2) process service with less than 20 feet of head in oil refineries or chemical plants. Each of these applications is discussed in some detail with respect to pump performance. A final section discusses "prerotation," or "backflow," in relation to pump design.

1221 WEBB, R. J. 1974 (Oct). "Maintenance Dredging, An Operations Research Approach," Terra et Aqua, pp 2-10.

This article describes a modelling approach to dredging operations which specifies dredgers for maintenance operations. It is pointed out that the exercise should involve considerations outside normal engineering practice. Dredging for maintenance of channels is a

conducted on the viscosity of methyl-methacrylate polymer spheres in aqueous solutions of lead nitrate and glycerol and in nonpolar suspending liquids (oils with small quantities of naphthalene). Four size ranges of spheres at concentrations from zero to 30 percent by volume were studied in the aqueous suspension using a "rising sphere type" viscometer. Measurements were accurate to within ±2 percent. Four conclusions were reached regarding the relative viscosity of these aqueous suspensions at a given concentration: (1) it is practically independent of shear rate up to volume concentration of 30 percent, (2) it is independent of the absolute size of the spheres, (3) it is independent of the viscosity of the suspending liquid, and (4) it is dependent on the size distribution of the spheres, decreasing with increasing size range to a constant value. In the nonpolar suspending fluid investigations, two size ranges of the same type of spheres were studied in a "falling sphere type" viscometer. Results indicated that relative viscosity varied from measurement to measurement, and the suspensions exhibited thixotropy. The rate of increase of the relative viscosity with time at any given concentration was greater for larger particles, and the relative increase in viscosity was greatest at the lowest concentrations.

1218 WARD, S. G. and WHITMORE, R. L. 1950 (Dec). "Studies of the Viscosity and Sedimentation of Suspensions; Part 2: The Viscosity and Sedimentation of Suspensions of Rough Powders," British Journal of Applied Physics, Vol 1, No. 12, pp 325-328.

In Part 1 of this series it was shown that relative viscosity of a suspension of smooth spheres is independent of their absolute size but dependent, to some extent on their size distribution. For other shapes of particles and for rough-surfaced particles, these conclusions do not apply. Using rough, irregular-shaped particles of methyl-methacrylate plastic, six samples were tested for viscosity in an aqueous solution of lead nitrate and glycerol. A rising-sphere viscometer again was used as for the spheres. Volume concentration of the sample was increased progressively from zero to about 25 percent. Corrections were applied for wall effects using the same Faxen correction used for spheres. Measurements were accurate to within ±2.5 percent. In contrast to suspensions of spheres, it was found that relative viscosity of the rough, irregular particles at a given concentration is dependent on particle size, increasing with decreasing average particle size. Relative viscosity at any concentration varies almost linearly with the specific surface of the rough powder. Again, in contrast to sphere suspensions, the size distribution of a rough powder has little effect upon its relative viscosity in suspension. Follow-up experiments on sedimentation rates were run to determine the effects of a "stagnant layer" surrounding the rough particles; this layer is an amount of liquid held in surface irregularities which increases the "effect volume." The liquid apparently is not adsorbed. The thickness of the layer is dependent upon the degree of surface roughness but not on the viscosity of the liquid. Layer thickness reaches constancy above a certain particle size.

pipe diameters of 10 to 12 inches and pipe lengths of 70 to 80 feet were maximum dimensions. Control of the winches, davits or gantries, and orientation of the pipe depended completely upon the skill of the operator. Today, a new system has been developed by Welin Davit and Engineering Company, Ltd., to afford maximum equipment safety and to relieve the operator from much responsibility. Use of this system has been successful on pipes of 12 to 36 inches in diameter, with lengths from 80 to 130 feet. The method of raising and lowering the pipes still is under davits with winch control. All pipe handling operations, hoisting, lowering, and securing in the stowed position are carried out by one man from a console. Controls are simple, involving only two switches. A swell compensator also is incorporated which permits work in swell up to 10 feet without raising the pipe from the bottom. A pipe indicator mounted by the console shows depth of the nozzle below the ship's keel (depth of echo sounder). Many safety features are built into the system, including limit switches, "fault lamps," and emergency bypass circuits. The operating package medium can be hydraulic or electric, as desired. Additional automatic features can be added to the system.

1216 WALLACE, H. 1974 (May). "Contract Specifications in Dredging Operations," Dock and Harbour Authority, Vol 55, No. 643, pp 2-5.

A number of themes dealing with dredging contracts is discussed. The engineer is realizing that his own efforts to achieve cost savings through selection of materials, specification, and design may be wiped out by management policies, such as selection of an unsuitable type of contract. Contracting in dredging is needed because of the scope and complexity of work; the substantial investments by both client and contractor; and the variability involved in plant availability, employed technology, weather conditions, and other factors. Dredging has an inherently high risk level, mainly because of: (1) cost of the dredging plant, (2) uncertainty of site conditions, (3) hazards of marine civil engineering, (4) unpredictable nature of the market, and (5) the inflexibility of supply to cope with short-term demand fluctuations. In contracting, if high risk is to be borne by the contractor, then he must be allowed to make profits commensurate with the risks involved. The client has to balance costs of taking part of the risk himself and the probable cost savings through lower contractors' prices, which should result. Taking the risk factor into account, the implications and consequences of 14 types of contracts are discussed. These types are grouped into three main categories: (1) fixed price, (2) special, and (3) cost reimbursement.

1217 WARD, S. G. and WHITMORE, R. L. 1950 (Nov). "Studies of the Viscosity and Sedimentation of Suspensions; Part 1: The Viscosity of Suspensions of Spherical Particles," British Journal of Applied Physics, Vol 1, No. 11, pp 286-290.

A brief review is presented first on the relative viscosity/volume concentration relationships suggested by researchers for smooth spheres in suspension. This is followed by discussions of two new experiments

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1213 WAKEFIELD, A. W. 1981 (Dec). "Jet Pumps -- Some Misconceptions Corrected," World Dredging and Marine Construction, Vol 17, No. 12, pp 28-29.

Several misconceptions about jet pump design and operation are dispelled. A jet pump is not a venturi device even though they look similar superficially; the principles of energy conversion and the energy losses for each are different. The fact that a jet pump has been regarded as a low head device, mostly suitable as a booster, also is incorrect. A jet pump can economically cover the spectrum from low to high stage head. In comparing hydraulic efficiency ratings between jet pumps and centrifugal pumps, efficiency at each stage of operation is computed. Overall efficiency for the hypothetical centrifugal pump turns out to be 22 percent, while for the jet pump, it is 18 percent. Another mistaken idea about jet pumps is that they are not affected by cavitation; that is true only if the pumps are correctly designed. Wear rate studies show that jet pumps used in extremely abrasive applications have mixing chamber lives of 1,000 hours, more than 10 times longer than the lives of hard alloy impellers in a centrifugal pump. When using jet pumps, advantages include reliability, negligible spare parts costs, reduced downtime, and reduced manpower needs.

1214 WALDECK, F. F. 1980 (Oct). "Centrifugal Dredging Pump Performance with the Hofer System," Proceedings, World Dredging Conference, WODCON IX, pp 389-399.

The development and operational characteristics of the Hofer Automatic Relief Valve System are described. The measure of success of hydraulic dredging is related to: (1) the uninterrupted feeding of the solids-water mixture into the pumping system, and (2) maintaining a feed of the highest solids percentage that the system can handle without choking, slugging, or plugging of the pipeline. Density and flow meters now on modern hydraulic dredgers register rate of production and general operating efficiency, but only after the dredged material has entered the pumping system. The Hofer system automatically permits loading of the pumping system to its optimum capacity, thereby increasing production with corresponding cost savings per unit of pumped material. Its principle of operation involves automatically opening a suction relief valve (letting in water) when discharge pipe pressure is reduced, indicating an imminent ram/slug or overloading; the reaction is almost instantaneous. In examples of use, the Hofer system had permitted hourly production increases of 25 percent while reducing diesel engine fuel consumption by 17 percent.

1215 WALKER, L. A. 1970 (Oct). "Suction Dredging: Dredge Pipe Control," Ship and Boat International, Vol 23, No. 10, pp 28-29.

A new, automatic control system for dredge pipe operations on vessels built solely for suction dredging is described. Originally,

cases when pipelines must be either perpendicular or parallel to shore. Two thoroughly described examples are given involving a trench for a sewage outfall in the North Sea, and a trench for pipelines in the Wester-Scheldt. Detailed siltation estimates using a variety of approaches to promote accuracy are described; these include model tests, prototype measurements, test dredging, and computations. For accurate predictions, detailed knowledge of boundary conditions is necessary.

1212 VINOGRADOV, S. V. 1978 (Jul). "Calculation of the Strength of Underground Pipes," Gidrotekhnicheskoe Stroitel'stvo, No. 7, pp 27-29.

Methods for calculating wall thicknesses and other conditions of strength for underground pipes are reviewed and compared. Under two-dimensional problem conditions, a unit-width ring is the design element. As experiments have shown, under the effects of an external vertical load (such as pressure from backfilling), the radial displacements of the pipe shell in the upper part of the ring are directed toward the pipe center, whereas on the remainder of the ring, the radial displacements are directed outward. Strength equations derived in another article on this subject are shown to be seriously in error; calculations using these equations yield underestimated values of internal forces in the pipe wall. The example used to substantiate that there are errors in the criticized method depicts a pipe of 1.02-meter diameter having sufficient underground strength with a wall thickness of 0.5 mm. For appropriate and accurate calculations, the "passive pressure-free zone" of the buried pipe must be taken into account.

deep-draft channels and 60 miles of shallow-draft channels. In an average year, dredges used in the District include 1 or 2 hopper dredges, 1 dustpan dredge, 1 or 2 clamshell bucket dredges, and 15 to 20 cutterhead pipeline dredges. Most dredging takes place in the southern part of Louisiana, where there are three deep-draft projects. Expanded discussions are provided for the following watercourses: (1) Baton Rouge to New Orleans channel, (2) deep water crossings, (3) New Orleans Harbor, (4) the Mississippi River Gulf Outlet, (5) the Calcasieu River and Pass, and (6) the mainstream Mississippi River. Dredging activities carried out by the District between 1968 and 1972 are reviewed. Numerous maps, tables, and photographs give support to the text.

1210 VICKARS, B. J. 1960 (Oct). "Dredging in Naval Ports, Review of Varied Types of Craft Employed," Dock and Harbour Authority, Vol 41, No. 480, pp 187-192.

There are four major naval ports in the United Kingdom and three abroad, where maintenance dredging in varying quantities is a continued commitment and capital dredging may arise at any time. For maintenance, each port has various types of craft based locally to cope with clearance of material from berths, docks, locks, and basins. For large jobs, a fleet of sea-going vessels is available. The activities, dimensions, and equipment associated with the following kinds of vessels and dredgers are reviewed: "dumb" grab dredgers and barges, self-propelled hopper grabs, sea-going multibucket dredgers, suction dredgers (none presently in active service), self-propelled hopper barges, and rock breakers. In addition, cathodic protection and maintenance of vessels are described. Several examples of dredging and reclamation problems (and their solutions) are provided. These include enlargement of Portsmouth Harbor, and physical modeling of Portsmouth Harbor and the Firth of Forth. A tabular appendix summarizes the dimensions and characteristics of all Admiralty dredging craft in service in 1959.

1211 VINJE, J. J. 1968 (Oct). "Siltation in Dredged Trenches," Proceedings, World Dredging Conference, WODCON II, pp 851-891.

After presenting a summary of factors affecting sediment transport, considerations involved in accurately predicting siltation rates are examined, especially as applied to trenches dug for pipeline installation. Studies concerning rates of trench silting are important for determining the proper construction method and the capacity of any dredger to be used. Predictions must be accurate and may require model tests or extensive computations. Both suspended load and bed load must be taken into account; calculation methods are given for determining movements of these materials. Although three main methods are available for marine pipeline laying (the barge-lay, reeled pipe, and bottom pull methods), the bottom pull method offers many advantages and was used in the examples provided. Dredging of trenches is described with respect to a number of criteria that must be met for suitable pipeline installation. Side slopes of trenches and bend radius are discussed. The choice of dredging equipment for various situations is presented assuming

1239 WOODYARD, D. 1972 (Jun). "Dredging -- But Fast," Engineering, Vol 212, No. 6, pp 565-568.

Several recent innovations are discussed which have aided in increasing overall speed, production, and efficiency of trailing suction hopper dredgers. Growth in size is one of the most important factors, accompanied by tremendous increases in available horsepower. Larger hopper sizes with wide bottom valves also have developed concomitantly with vessel size. Use of twin hoppers and rearrangement of machinery has increased load capacities of some vessels. Automation for indicating draghead depth, flow rate, solids concentration, and hopper load is contributing to optimize production and efficiency. Boosting the cargo discharge rate is an obvious way to increase efficiency by keeping the plants dredging and attaining more cycles per day. One new system is described for unloading hoppers from above by using a bucket scraper system which deposits dredged material onto conveyors. This method takes only half the time of shoreside grab cranes for unloading. A concluding section describes the advantages of a floating rubber discharge hose system known as "Selflote." It is a replacement for the heavier and more rigid pontoon-supported steel pipeline. Selflote lines can withstand greater wave action, increase operating time by more than 30 percent, and incur less maintenance costs.

1240 WOOTON, F. T. 1980 (Apr). "Dredging and Disposal of Toxic Material Using Japanese Technology Suggested for United States," World Dredging and Marine Construction, Vol 14, No. 4, pp 14-15.

The Norfolk District of the U. S. Army Corps of Engineers maintains about 30 miles of channel and 65 small boat harbors. Maintenance of the channels is becoming difficult because of the lack of dredging technology needed to complete dredging while complying with existing environmental standards. In the James River, Virginia, a very dangerous herbicide (Kepone) was deposited intermittently between 1967 and 1974. An amount between 21,000 and 42,000 pounds was added to the James River system. Taking of fish was prohibited by the State Governor, but it was important to keep the federal waterway open because of its importance in the transport of sand, gravel, petroleum, fertilizer, sulphur, seafood, and newsprint. A delegation from the Norfolk Corps District and the U. S. Environmental Protection Agency visted Japan to investigate dredging methods used there which act to significantly reduce secondary pollution from disturbed sediments. A dredge known as the "Oozer" carefully sucks up polluted sediments, discharges them to a rehandling barge or to a holding area. Effluent in treated in a special treatment plant to remove pollutants, and sludge is detoxified and solidified for conventional landfill deposit (upon which industrial sites later develop). This soil fixation process is extremely effective and may be useful on Kepone, PCB, or other pollutants in dredged material in the United States. The "Oozer" was shown to be capable of dredging most places in the James River.

1241 WORKNEH, H. G. 1956 (May). Hydraulic Transportation of Solids in a Horizontal Pipe, Ph. D. Dissertation, Carnegie Institute of Technology.

An experimental and analytical study of hydraulic transport of sand is described. Initially, 107 previous theoretical and experimental investigations in the literature were reviewed, showing that data are meager and inconsistent. The present experiments deal with velocity, pressure drop, solids concentration, and flow patterns measured in a 2-inch-diameter transparent pipe. The sand used was from Ottawa, Illinois, and had a mean diameter of 0.6 mm and specific gravity of 2.66. Only solids concentation and flow velocity were varied. The concentration of sand varied up to 43 percent by weight; velocities were up to 12 feet per second. Sand particle movements were recorded on high speed film at a rate of 600 to 1000 frames per second. Conclusions state that: (1) pressure drop decreases as velocity decreases (for a given sand concentration) until reaching a minimum pressure drop at the "critical velocity" where solid material begins to lodge in the pipe; (2) the critical velocity increases with an increased percentage of sand in the mixture; (3) at velocities higher than the critical, the pressure drop approaches that of clear water; (4) from photography, the mean velocity of sand particles for various concentrations of sand and rates of flow of mixture is about 0.87 times the mean velocity of the mixture. The maximum velocity was found to be between 56 and 70 percent of the pipe diameter above the bottom.

1242 WORSTER, R. C. and DENNY, D. F. 1955 (Sep). "The Hydraulic Transport of Solid Materials in Pipes," Engineering Digest, Vol 1, No. 10, pp 49-52.

A general overview of the behavior of solids transported hydraulically through vertical or horizontal pipes is presented. Important results from research on the subject are summarized for a number of specific topics: maximum particle size, pressure gradients, nonuniform mixture densities, head loss, stability and safety factors, settling velocity, and pumping methods. Various pumping methods for long-distance pipelines include several centrifugal pumps in series, use of positive displacement pumps, and feeding solids into the line once the water has been raised to the necessary pressure. Closed system and open system cycles for transport of coal and other materials are reviewed. It is noted that flow conditions are much simpler in vertical pipes. The maximum size of solids that can be passed through a pipe is not easy to determine; however, it is pointed out that the rule which says that the maximum size of solids is limited to one-third of the pipe diamter is applicable only at moderate concentrations and if speeds are low. A number of graphs are used to illustrate points concerning pressure gradients along pipes and effects of particle slip.

1243 WUNSCH, W. and PUFF, W. 1965 (Apr). "Method of Transporting Solid and Viscous Material in Pipe Lines," U. S. Patent No. 3,180,691.

A patent is described relative to transporting solids in pipe lines by means of a liquid carrier medium. With known methods, the difficult and expensive separation of the carrier medium from the goods being transported has been a considerable drawback; this drawback is overcome by the proposed method. The proposed method gives an economic and relatively simple way of separating the transported medium from the carrier. The method presented involves using a medium which is liquified by compression at the start of the pipeline and at the destination end will be gasified by prevailing temperature and atmospheric pressure. It will be held in the liquid state during transport. The substances considered as possibilities for carrier media include the following (or mixtures thereof): propylene, propane, difluordichloromethane, methylchloride, i-butane, n-butane, monofluortrichloromethane, and n-pentane. For long pipelines, booster stations may be necessary to maintain necessary pressure. In some instances of fuel transport, no separation may be needed. An example is provided using hard granular coal with propane as a carrier. Six claims for the method are shown in the patent.

Y

1244 YAGI, T. 1970 (Sep). "Sedimentation Effects of Soil in Hopper," World Dredging and Marine Construction, Vol 6, No. 11, pp 39-41.

The production of hopper dredges depends on draghead suction capacity, dredge pump capacity, and sedimentation effects of soil in the hopper. The loading efficiency of hoppers is derived and presented considering a large number of factors which influence soil sedimentation and which control delivery flows and overflows. Typical hoppers on United States and Japanese vessels are compared to three sizes of model hoppers on which experiments are conducted. Loading efficiency is 100 percent until the beginning of overflow; it then decreases until sooner or later it becomes zero with saturation. The studies here do not include in the economic loading analysis such factors as price of vessel, recovering costs, repair and labor costs, and so on. Conclusions reveal that: (1) for soft mud, it is recommended to suck up high concentrations because additional loading after the beginning of overflow is not expected; (2) for coarse sands, loading is restricted mostly by the vessel's draft; and (3) for fine sand, the problem of operating and loading efficiency is most important and should be picked at an adequate loading such that the cycle is most efficient.

Z

1245 ZANDl, I. 1967 (Feb). "Decreased Head Losses in Raw-Water Conduits, Journal, American Water Works Association, Vol 59, No. 2, pp 213-226.

It is now apparent that water carrying a small amount of particulate matter produces less head loss than when water alone is flowing, all other conditions being the same. This article brings this point to the attention of water industries engineers, and presents new data on solid-water systems. A background literature review is provided from the earliest work revealing this phenomenon (by Blatch, 1906) up to the present. One observer noted that this occurred in streams also, that muddy water flowed faster than clear water at a given river stage. Experimental mechanisms and methods are described in which four finely divided particulate substances (coal, charcoal, clay, and ash) were measured flowing in pipes ranging in diameter from 0.5 to 2 inches. Varying flows and concentrations were employed in the tests, and head loss was measured and compared to clear water. Maximum and minimum head loss data are shown for all runs; almost all data points fall below corresponding points for clear water. In pipes of 1-, 1.5-, and 2-inch diameters, clay cuased the most head loss reductions; in smaller pipes, charcoal had the greatest effect. Previous studies on turbulent systems and studies with other particles and fibers are reviewed. The findings are ultimately related to raw-water withdrawals from reservoirs, showing several advantages which might be realized.

1246 ZANDI, I., (Ed.). 1971. Advances in Solid Liquid Flow in Pipes and Its Application, Pergamon Press, Oxford.

Because such a diverse group of industrial processes; utilities; and construction, navigation, sanitation, or water resources organizations are involved with some form of mixed solid-liquid flow phenomena, the available knowledge on solid-liquid flow is scattered through the literature of a large number of professions. This volume brings together works of many individuals from various disciplines, and is concerned primarily with the transport of solids in pipelines. A total of 21 articles by 38 contributors is included. Most articles were presented at the 1968 "International Symposium in Solid-Liquid Flow in Pipes and Its Application to the Collection and Removal of Solid Wastes." The collection of articles given here is intended to present highlights of recent research in several facets of solid-liquid flow. Among the topics covered are hydraulic transport of bulky materials, turbulent flows of suspensions, low concentration transport, heterogeneous flow of heterogeneous solids, pressurized and nonpressurized flow, grinding of crushing for pipeline transport, new solids pumping techniques, and several aspects of sanitary sewage transport. Each article is suiltable illustrated with charts, photographs, drawings, or tables of data.

1247 ZANDI, I. and RUST, R. H. 1965 (May). "Turbulent Non-Newtonian Velocity Profiles in Pipes," Journal, Hydraulic Division, ASCE, Vol 91, No. HY5, pp 37-55.

Five previous studies have been reported involving the measurement of velocity profiles of the turbulent flow of non-Newtonian fluids and suspensions in pipes. Two other studies have attempted to predict such velocity profiles using semiempirical models. The purpose of this study is to formulate and to verify with reported experimental data, a method that enables prediction of velocity profiles of turbulent flow of non-Newtonian fluids or suspensions in a smooth circular tube from the knowledge of the rheological parameters of the fluids and conditions of the flow. Theory and derivations of relevant formulas are presented along with assumptions of the proposed method. Conclusions are that the method has advantages over previous works because: (1) it predicts velocity across the pipe cross section and produces a continuous profile with good accuracy; (2) the model is based on the physical concept of turbulent motion and boundary layer theory and, therefore, the equation has physical meaning; (3) it predicts the velocity profile better than other methods; and (4) no parameter is involved which requires evaluation for each individual profile, which is the case with other methods using semiempirical equations that predict the complete velocity profiles.

1248 ZANKER, K. J. and BONNINGTON, S. T. 1967 (Oct). "Recent Research Developments in Hydraulic Dredging," Proceedings, Institution of Civil Engineers, Symposium on Dredging, Paper No. 9.

A review of the suction dredging process is presented based on the assumption that it is basically a trial and error process involving "shifting of a largely unknown amount of muck an unknown distance." Horizontal transport of solids is discussed with respect to critical velocity, particle size, and power consumption. In a similar fashion, vertical flow and inclined flow also are described. Design parameters and characteristics of jet pumps are presented. Jet pump operation is one of exchange of momentum between the driving jet and entrained fluid, and this exchange requires a "mixing length" of 6 to 10 diameters. Cavitation occurs in jet pumps as well as in centrifugal pumps. It is shown that 20 to 30 percent solids concentrations (by weight) can be entrained by a jet pump if the jet unit is immersed in unconsolidated solids. Multistage jet pumps are described; these can produce a combined flow ratio about double that of a single-stage unit. In a system in which the driving pump and jet unit are matched to each other and to the job, there is little advantage in using a multistage system. Other topics examined include compressed-air driven jets, design and performance of centrifugal pumps, measurement and control of output, and conditions at the suction head. The main problems of centrifugal pumps in transporting solids are those concerned with wear. The jet pump has many advantages over centrifugal pumps; the main disadvantage is a low efficiency of about 30 percent maximum.

1249 ZVOLANEK, V. 1974 (May). "Czech Research Institute Aids Industry," World Dredging and Marine Construction, Vol 10, No. 5, pp 48-49.

When dredge production began in Czechoslovakia in 1951, a consulting organization called Navika, later the Research Institute for Shipbuilding, designed the dredges for the shipyards. Funding came partly from the state and partly from shipyard contracts. The Research Institute is established to solve problems in the function of a ship or dredge. Several innovations developed and tests conducted by the Institute are briefly described here. One innovation was a monitoring system in which all engine controls are operated from the pilot house; this includes starting of engines, regulation of cooling and lubricating, and operating of carbon dioxide systems. An instrument known as the "induction flowmeter" also was developed here based on Faraday's Law. Other control instruments include a "deviation transmitter" and a "rope pull transmitter." One of the tests conducted by the Institute concerned performance of various types of suction heads for dustpan type hydraulic dredges. All tests were done on models in a specially built towing tank. Jet nozzle applications on dustpan heads were tested in conjunction with head design.

A

A0290 "Aid to Dredge Positioning Introduced by Motorola," World Dredging and Marine Construction, Vol 8, No. 5, Apr 1972, pp 8-9.

A new electronic package, called the "RPS Survey System," is described. Its purpose is to maintain accurate dredge positioning during operations. Corps of Engineers requirements include simplicity, reliability, and ruggedness, with the capability to integrate position and depth data and present the data for rapid conversion to navigational or dredging charts. Test demonstrations included recording position and water depth data along two base courses, offsets of 50 and 150 feet from the base course, and along three cross-channel lines. The probable range of error was given as less than 10 feet in 50 miles, but the test data were accurate within 2 feet. The system measures the distance to two small shore-based reference transponders, which is automatically converted by trilateral calculations into X-Y coordinates. Operator console adjustments permit course selection or offsets to a base course. An additional feature is the track plotter, which marks the course number, start and stop points, and plots the vessel's actual track along a preselected course. Digital depth readings also are presented on the console, and position and water depth data can be recorded on the system's cassette tape at intervals ranging from 0.5 to 9 seconds.

A0291 "Aids for Doing a Better Job, Electronic Equipment for Dredges," World Dredging and Marine Construction, Vol 18, No. 5, May 1982, pp 30-35.

General applications and descriptions are presented on new electronic devices from ten commercial firms. All items are intended to improve efficiency of dredging operations. One item is an on-board microcomputer which permits an operator to know the correct dredge level regardless of tidal fluctuations or boat waves. Another item is a compact system for monitoring diesel engine conbustion performance, thereby allowing accurate load adjustments. Devices for obtaining positioning data include a satellite navigation system and a digital readout remote magnetic compass for use in stable applications. A voltmeter for corrosion and cathodic protection testing of buried or immersed metallic structures is introduced. An ocean bottom mapping system is announced which enables production of seafloor mosaics up to 5 km wide with only five survey lines. The system's variable tilt transducers are good for rugged terrain and steep-slope situations. Other introduced equipment includes a time code generator, submersible DC motor, hand-held vibration analyzer and an electrical contactor with a variety of features.

A0292 "Australian Company to Market Bucket Wheel Dredge," World Dredging and Marine Construction, Vol 16, No. 12, Dec 1980, pp 29-30.

An improved technique for inshore dredging and shallow-water mineral extraction is introduced in the form of a steel-toothed, bucket-wheel dredge, which is more efficient than the conventional basket-type

wheel. Because it can pump up to 600 cubic meters per hour with almost no spillage, it may be an excellent tool for extracting tin, gold, silver, and other metal ores. The dredge is 40 meters long, 8 meters wide, and weighs 156 tons. It can be disassembled and transported on five trucks. When transported, the largest dredge section is 10 meters long and 3.6 meters wide. The bucket-wheel dredge originally was designed for rough use in coastal areas with mangrove roots and trees embedded in old peat beds. The eight buckets on the wheel can consume almost anything they bite. Dredged material can be pumped up to 2,000 meters from the dredging site by the standard pumping equipment, and the system can operate at depths up to 30 meters. A spud carriageway system allows rapid relocation. The spuds, which anchor the stern, are lifted by hydraulic rams and released by a quick drop system that allows free fall and maximum underwater bed penetration. The carriageway also allows a 3-meter forward dredge travel to increase its arc of operation.

B

293 "Boca Raton Panel Explores How Slurry Pipelines Raise Special Problems," Oil and Gas Journal, Vol 55, No. 5, p 104.

The placement of slurry pipelines incurs special design, engineer-g, supervision, and construction costs over and beyond those expected om oil or gas product lines of the same diameter and in the same loca-on. Most of the unusual construction requirements of a slurry pipe-ne result from slope limitations. Grades and vertical bends cannot be cessive or efficiency is lost and repairs are too frequent. On the ample given, an 18 percent grade and a 10 degree vertical bend were e established limits. An additional cost is the need for thicker pipe lls nearer the initial slurry source because of increased abrasion ere. In the 108-mile-long line described, wall thickness was 0.667 ch at the source and 0.375 inch at the other terminus. Considering ditional costs for unusual weather, a winter layover, working on a rrow right-of-way, and extra ditching, welding, and cleanup costs, the st of installing the coal slurry pipeline was estimated to be 1.6 mes the cost for installation of a normal 10-inch products line.

C

)4 "Clearwater Undertakes to Do Its Own Dredging," World Dredging and Marine Construction, Vol 18, No. 4, Apr 1982, pp 6-8.

One Gulf-coast city is realizing substantial savings and main- ıing complete project control by purchasing its own dredge and asso- :ed equipment. Clearwater, Florida, is dredging 1.1 million cubic ls of sand from an inlet and building two stone jetties to prevent l migration back into the inlet. Deepening and widening of the inlet ıecessary to restore lower velocity to its waters and thereby mini- : erosion, especially around pilings for a toll bridge. The dredge : the city about $350,000; associated equipment such as a derrick ;e, small work boat, and front-end loaders cost another $200,000. loader was modified as an all-terrain forklift for carrying dredge :, and $12,000 was spent on surplus parts to alter the barge for ry lifting jobs. The dredged sand is used to widen a section of :h; to accomplish this, an extra mile of pipeline, an auxiliary pump- station, and a swamp dozer were purchased for $250,000. Even with city engineers and other labor included, the cost to the city is ıt half that of obtaining a commercial firm. The city plans to make dredge available to neighboring Gulf-coast cities for similar jects.

)5 "Crawler Drill Modified to Work Underwater," Engineering News-Record, Vol 196, No. 13, Mar 1976, p 16.

A modified conventional tractor drill is developed to assist in ;ting to deepen a harbor off the northwest coast of Wales. Deep :r, tight quarters, and extreme tides limited the use of a drill ;e; therefore, a self-propelled crawler drill was used which would be affected by high winds, rough water, or 25-foot tides. The vler drill is five times more effective than divers using hand- :ated, air-powered drills. The crawler is an Ingersoll-Rand fitted ı lengths of rubber hose, special gaskets, and 3-foot extensions to controls for driver safety. All air exhausts lead to the surface to ıd disturbing silt and reducing visibility. The hydraulic breather :he hydraulically powered boom also leads to the surface. All bolts secured with wire or gasket cement. For efficiency, experienced llers were trained as divers to drill 4-inch-diameter holes 20 feet) in a 10-foot grid over 3500 square yards of harbor. The drill can ıer be walked in from shore or carried aboard a work barge and set)lace with a crane. Because the drill lacks floatation tanks, which rupture when a nearby charge explodes, the drill has to be backed 7 only 10 feet. Daily maintenance includes operating compressed air)rs at full speed, changing the hydraulic oil, field-stripping the ımatic hammer, and wiping on a protective coat of oil. Friction)ugh the compressed air hoses reduces normal working pressure from to 110 psi; water depth cut this to 80 or 90 psi.

D

"Directory of Dredge Pumps," International Dredging and Port Construction, Vol 3, No. 19, Apr 1976, pp 23-29.

A listing of dredge pumps is provided. Manufacturers names, lo-
ıs, and telephone or telex numbers are given along with trade names
Pump data listed include diameter size range (suction and dis-
e), maximum power rating, maximum discharge distance, rated capac-
and material of manufacture. An effort was made to compile as com-
ısive a directory as possible, but it was noted that questionaires
to many companies were not returned by the time of printing. In-
tion from 20 manufacturers is presented.

"Double Walled Pump," Ports and Dredging & Oil Report, Vol 3, 1977, pp 17-19.

This article expounds on the durability, cost effectiveness, and
aintenance requirements of the I.H.C. line of double walled pumps
redging operations. Origniaily, many comsumers were hesitant to
ase because of higher price. After 5 years, data are available to
that the pumps were worth the extra money. Minor design changes
been made to upgrade the suction side cover and the impeller
ed only in operations encountering very hard materials). The inner
housing needed no modifications. Automatic continuous flushing of
uffer space in the outer housing has recently been incorporated
the design. Wear of parts is discussed at length, and routine re-
time estimates are given for replacement installations. Balancing
igher initial cost are longer component lives and shorter replace-
times for parts. Experience has shown that, in sufficiently abra-
soils, the additional cost of a double walled pump can be recovered
to 1.5 years. The inner housing life, in operating hours and re-
time, is estimated to be at least five times greater than that of a
ntional silicon-manganese housing. Maintenance is generally
ed to rotation of the wearing ring to even out wear, and occasional
ler and inner housing replacement.

"Dredger Blows Mud and Silt into Suspension," Engineering, Oct 1962, p 431.

A line of four dredging craft is described; all are small dredges
ne is a type not previously marketed. Three types are briefly men-
d, but the bulk of text is given to the fourth type, the "Hydro-
atic." This dredge's principal application is silt, sand, and mud
rsal, but it could be used for sinking piles or simply as a power
e for other pneumatic tools. It can also operate as a fire float.
pressure water and air are fed by separate hozes into nozzles where
ete mixing is accomplished. The nozzles are positioned on a frame
is submerged by a stern-mounted crane above the material to be dis-
d. Jet force from the nozzles causes an arc to be described, and
s are applied to a wide area. The benefit of this device is

ed as the ability to place mud in a state of suspension, such is indistinguishable from the solids naturally carried in a here silting normally occurs. Diesel engines drive the centrifter pumps and an air compressor. Two hull arrangements are of- one is a barge type with all machinery below decks; the other is on type with main machinery mounted on deck. The former provides gh handling in confined areas (or among shipping) and for crew dations. The latter is less costly and more easily portable.

"Dredge with Hydrostatic Drives," Fluid Power International, Vol 33, No. 386, May 1968, pp 48-49.

This article describes a 47-foot-long by 18-foot-wide dredger, ain advantage is the use of fluid power. In contrast, comparable cal systems on this size dredger have experienced problems be- f the operating environment. Another advantage of the hydraulic on this size vessel is that they are less subject to damage from ding or abuse. The small inshore dredger is a 10-inch, spud- cutter suction type capable of pumping at a rate of 100 cubic er hour for a delivery distance of 2,000 feet. The main features : hydraulically driven winches with pneumatically actuated and brake systems; a rotating cutter head/suction dredge system by a hydraulic, slow-speed, radial piston motor; and two stern paced so that the dredge can swing around each one in turn while ing and advancing into a cut. By alternating spuds, the craft lk" itself forward. The main engine is diesel, and all pneumatic raulic controls are desk-mounted in the bridge house. Air supply ined from a compressor driven from the rear of the main engine.

"Dual Capacity Advantage: Bucket Dredging Minimizes Job Costs While Maximizing Equipment Use," World Dredging and Marine Construction, Vol 17, No. 12, Dec 1981, pp 6-7.

Three examples are given in this article regarding combined use ral dredge types. The advantage of using a mobile barge with a -yard backhoe to perform bucket dredging and power plant intake pairs was described first. When high winds curtailed water-based ons, crews towed the barge to shore to assist in fabrication of el parts to fit the crib. Frequent repositioning ease and avoidance in surf zone excavation were credited to the mobility bucket dredge. A second example included routine dredging to date shipping, and disposition of polluted river sediments in a isposal facility, which also was designed to protect unique wet- A combination of hydraulic and bucket dredges was used on clay re, riprap stone, soft clays and sands, and virgin materials. A ll derrick with a 10-yard bucket replaced a 22-inch, 4000 horse- ydraulic dredge which could not economically remove clay with s up to 3 feet in diameter. The final example describes the marine construction flotilla ever used on the Great Lakes: 30 dredges, and tugs, of which bucket dredges were most important. mense project on the J. H. Campbell Power Plant was completed on

due to versatility of bucket designs and ease of repositioning. ıvations were 30 feet below the lake floor in water depths of The article concludes that a revived demand for bucket dredges ılt from increasing classification of polluted dredged material .rements for minimal disturbance.

AD-A157 539 DREDGING: AN ANNOTATED BIBLIOGRAPHY ON OPERATIONS EQUIPMENT AND PROCESSES..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 1985 3/4

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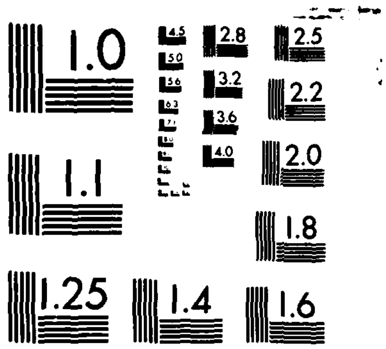

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E

A0301 "'Eagle I', A Showcase of the Latest Dredging Electronic Equipment," World Dredging and Marine Construction, Vol 17, No. 3, Mar 1981, pp 28-30.

The world's largest split-hulled, trailing suction hopper dredge is described. The dredge was constructed at Avondale Shipyards in New Orleans at a cost of over $30 million. Advances in electrical engineering and a wide array of electronic alarm and control systems permit the vessel to be run by relatively few people. The machinery control room on the crew deck permits the ship to sail with the engine room unmanned. Four large panels in the machinery control room comtrol propulsion, dredge engineers and gearboxes, and damage monitoring. The latter panel monitors damage in case of collision, closes watertight doors, switches off fuel to affected areas, starts fire pumps, and floods a fire-affected area with carbon dioxide. The wheelhouse contains the "heart and soul" of the dredge. A large panel there contains controls for all dredging functions from dragarm suction to material discharge. The panel also contains an echo sounder and load and draft indicator.

F

A0302 "Further Information About Dragheads," Ports and Dredging, No. 30, pp 3-5.

Research and development of a new draghead design for I.H.C. Holland is explained. This particular draghead is especially useful in areas where soil and sand have become hard packed, and where conventional dragheads tend to "dance," flatten out against the bottom with reduced concentration of dredged material, or slip. The new design incorporates a freely hinged visor part on the rear of the dredge which automatically adjusts the angle of attack, keeping the height of the free slot behind the draghead appropriate so that the quantity of water sucked up is optimal. The maximum height of the slot depends on soil type and, although it is not expected that difficult types of soil will suddenly be easy to suck, the new draghead type will ensure more uniform performance and efficiency even if the free slot height had not been correctly chosen initially. Testing in the field met the expectations from the laboratory, and patents have been applied for.

G

A0303 "Gold Dredging in New Zealand," Chemical Engineering and Mining Review, Vol 41, No. 125, Jan 1949, pp 125-128.

A brief history of dredging for gold in New Zealand coastal waters is presented, dating from the 1860's to the immediate post-World War II times of 1945 to 1947. Dredging first began using "spoon" dredges and current-operated wheel dredges in the 1800's. By 1899, 70 dredges were operating. This number increased to 228 in 1900, but then a decline began for a number of reasons. By 1926, only five dredges remained working the flats for gold. Somewhat of a revival began in the 1930's, and dredges capable of operating to 100 feet deep were introduced. In 1940, a peak was reached; 24 dredges recovered 90,018 ounces of fine gold. The remainder of the article describes operations data of six large dredges, giving the following types of data: cubic yards treated, yards recovered per hour, gold recovered, value of recovered gold, and operating cost. The article concludes that a rise in the price of gold would be of great significance to the industry, but "such a rise would have to be substantial."

H

A0304 "Hydraulic Transportation of Coal, Progress of Scottish Experiments," Iron and Coal Trades Review, Vol 168, No. 4497, Jun 1954, p 1519.

This article is concerned with experiments at a Scottish coal mine (Woodend Colliery) to bring about efficient slurry pumping of coal. The experiments to date have mainly dealt with vertical elevation of the coal. Researchers anticipated that using water slurry pumping could be designed to recover 1,000 tons per day. This would require a large volume of water and probably a closed circuit system. Major difficulties thus far in experiments have been in devising an apparatus to feed crushed coal into the moving column of water (6-inch pipe) under pressure. No problems were encountered in screening coal, pumping the water, or elevating the coal in the pipe. Water to pump the coal is in great excess of that required in the surface washer; therefore, experiments are continuing in removing fine coal particles from the water. Horizontal transportation is to be evaluated later because of anticipated problems with coal particles settling and forming solid layers or blocks in horizontal pipe systems. The report concludes that, if successful, the "economies in raising coal would be substantial."

A0305 "Hydraulic Transportation of Solids," Colliery Engineering, Vol 32, No. 375, May 1955, pp 185-190.

The hydraulic transport theories of homogeneous and heterogeneous mixtures of water and solids in pipes is explained in this article. The intent is to derive equations to understand and evaluate the feasibility of transporting large quantities of coal over great distances. Advantages of conveying solids in pipes are given as: (1) system is relatively easy to install; (2) roadways, inclines, etc., offer no serious obstacles; (3) few people are needed for installation, maintenance, or operation; (4) moving parts are confined to pump stations; (5) automatically controlled operations are realistic; and (6) costs are low under many conditions. The paramount conditions to know in setting up a system are described as optimum velocity in a given pipe at a given concentration of solids and ability to estimate loss of head. Particles of 30 microns or less were determined to behave much like a homogeneous mixture with water, whereas, if particles are larger than 50 microns, turbulence is insufficient to maintain complete homogeneity. Particles between 30 microns and 0.2 mm follow turbulent flows, but particles in excess of 2.0 mm simply travel by successive leaps (saltation) on the bottom of pipes. This means that laminar flows should definitely be avoided, but it was also shown that head losses become independent of particle sizes when particles exceed 2.0-mm diameter.

J

A0306 "Jubail, Arabia's Port of Kings," Supplement to New Civil Engineer, Jul 1976, pp 11-14.

A giant industrial/commercial harbor project for Jubail is intended to relieve the port of Damman, where delays to shipping have run to many months. At the time, this was the largest construction job ever in Saudi Arabia; it involved building 20 km of 30-m-wide causeway and breakwaters, 37 million cubic meters of dredging, and placing 11 million cubic meters of imported stone fill and 3.3 million cubic meters of concrete. Work was split between two dredging companies for time savings. Both contractors began using four large cutter-suction dredges, but the seabed caprock (up to 1.5 m thick) was harder than concrete. One dredger, the Jim Bean, with a capacity of 120,000 cubic meters per week in soft ground, achieved only 10 percent of capacity and was wearing through 300 pick points weekly with a 40 percent downtime. As many as 40 welders were on site for maintaining pick points on the one dredger. Caprock was harder in another area, and explosives were contemplated for some locations, with a clam-shell dredger removing overlying spoil. Construction of the harbor itself and offshore berths for four 300,000-ton supertankers involves an even larger contract to a consortium of West German and Lebanese contractors.

K

A0307 "'Kaser', A Dipper Dredger with Rockbreaker Installation," Ports and Dredging, Vol 3, pp 8-9.

Kaser means "breaker." It is the name for a new dipper dredger with rockbreaking capability that was built by I.H.C. Holland for the Suez Canal Authority to use in the canal. At some places in the canal, rock layers under the desert sand make use of a cutter-suction dredger or bucket dredger unsuitable. This new vessel has an electric-winch-driven 22.5-ton rock cutter, which is provided with interchangeable hard steel point and is positioned in a guiding tube. During rock breaking, five anchors position the vessel. The dipper has an 85-cubic foot capacity and can operate between 0.5 m above to 19 m below water level. Similarity, the rock cutter can operate from 0.5 m above to 20 m below water level. The dipper hoist and dipping winch operates on 240 horsepower. To withstand the digging force of the dipper, during dredging the pontoon is raised 2 feet on two working spuds. The dredging operations are all controlled from a forward dredgemaster's cabin. Three diesel-driven generators supply power for all equipment and the ship's network. Spacious living quarters for two officers and a crew of eight are installed on top of the winch deck house.

N

A0308 "New Dredging Systems for Gravel," Quarry Management and Products, Vol 52, Jul 1977, pp 177-182.

Dredging operations are described for deepening and increasing capacity of the Queen Mary Reservoir at Staives, near London's Heathrow Airport. A total of 404 acres are being dredged to increase capacity by 1.5 billion gallons. Commercially valuable aggregate materials comprise much of the dredged material. To operate in water up to 40 feet deep with little disturbance to the reservoir, a new Pressair dredger is used. This suction dredge works well on compacted gravel, producing considerably more than 400 tons per hour of gravel and the 650,000 tons per year needed to keep a land-based processing plant in full operation. The main advantage of the Pressair system is that it is more efficient at increasing depths because of its design. Air is forced down the outside sleeve of a twin dredging tube into a special head with rotating cutting teeth and nozzles. When the air reaches this point, hydrostatic pressure is less than that of surrounding water, resulting in a rapid upward suction in the inner tube, conveying with it all sediment and aggregates. The ratio of water to aggregate can be as low as 2 to 1; it was 3 to 1 on this project. Only two men are required to operate the dredges, one at the dredger controls and one for mooring barges and performing other tasks.

A0309 "New Non-Linear Sub-Bottom Profiler System," Dredging and Port Construction, Series 2, Vol 8, No. 4, Apr 1981.

Three new electronic devices applicable to dredging are presented. They were initially developed for deeper offshore operations by Ulvertech, Ltd. Primary usefulness lies in their ability to accurately portray seabed contours and structures and subbottom layers and densities. One item, specifically designed for nonlinear subbottom profiling, nests in a stabilized platform which can even out a roll and pitch of 20 degrees within 3 seconds while carrying out survey transects at 10 knots. The device has been most used in European areas where constant silting and year-round dredging occur. This system can penetrate the seabed to 20 meters. Narrow bean widths are achieved using a 0.3-meter-diameter transducer, as opposed to conventional transducers of 2-meter diameter. Resolutions on the order of 10 cm are possible. Seabed interface echo sounding accuracy can be ±2 cm. Applicability is in the range of 2 to 50 meters from the seabed. A second device is a mechanical scanning sonar system designed for submersible mounting. It is particularly good for seabed and pipeline profiles or postwar dredging surveys. It is rated to a depth of 1,000 meters and has both a visual readout and recording system. A sonar video system also is available, consisting of a conventional television monitor and a rolling-map type display. Its power is 115/240 VAC, and it can be linked to a video recorder. Display range is variable from 1 to 10 m/sec. An attractive survey feature is a freeze switch, enabling a particular display to be held.

A0310 "New Suction Side Seal for Dredge Pumps," World Dredging and Marine Construction, Vol 16, No. 7, Jul 1980, pp 14-17.

A new design of suction-side seals for dredge pumps is described. It is known as the "threaded bush type flushing water seal." The principal of the new seal design is to greatly reduce or eliminate abrasive wear by sand particle dredging caused by leakage between the impeller and cover. This wear is proportional to the width of the gap and the pressure differential. About 20 preliminary designs were tested to meet nine criteria relating to robust construction, ability to withstand pressures and peripheral velocities, useful life, and minimal leakage and wear. The resulting final design consists of a stationary rubber sleeve which runs on a bush with screw-thread grooves. A water transporting action in the direction of the low-pressure side of the seal occurs and, under the influence of pressure differential, a continuous leakage current lubricates and cools the sealing surface. This current is about 10 percent of the flushing water. Provided the flushing water is "clean," abrasive wear of the sleeve and bush is prevented. The seal rotates in a so-called water chamber which is equipped with a barrier to prevent ingress of sand. The simple construction ensures reliable operation, rapid removal, and easy replacement. The seal is suitable for all suction inlet diameters.

P

A0311 "Power Systems in Dredging," World Dredging and Marine Construction, Vol 9, No. 8, Jun 1973, pp 14, 16, 18.

The history of power sources used for dredging is given, along with examples of power requirements in modern projects and one particular project--construction of the 4-mile-long Bayport, Texas, Ship Channel and Turning Basin. The first attempts to remove material from water bottoms was manual, then animals were used and, eventually, mechanical power from steam-driven and internal combustion engines came into use. Diesel engines have proven to be safer, more economical, and perform better than gasoline engines because, operating at lower RPM's, direct drives to pumps or lower reduction gear ratios are possible. Electrical power also has wide use now because of its ease of distribution to a variety of loads. It was found that, typically, the main pumping system requires 50 to 60 percent of total horsepower requirements, while cutter power and hoist power usually runs 25 to 30 percent. Auxiliary equipment, service machinery, communications, and crew support facilities use the remainder. Cutter power most frequently is provided by electric motors or by motors driving hydraulic systems. Various hoisting gear may require electric motors of up to 500 horsepower each. Boosting stations also are frequently used to operate efficiently. The Bayport Ship Channel job utilizes a 900-horsepower cutter, 4500 pumping horsepower, and three boosters totaling 14,000 horsepower.

A0312 "Prins der Nederlanden, Largest Trailing Dredger Afloat," Ports and Dredging, No. 59, 1968, pp 4-7.

The very large dredger described in this article has come into demand more and more with increases in size of tankers and bulk carriers, and for creating suitable deepwater berths and approach lanes. They are more economical, affording lower cost per unit of spoil; however, they themselves are limited by water depth. The hopper on this vessel is 179 feet, 2 inches long and can hold 9,000 cubic meters of spoil (about 18,000 tons). This amount can be dredged in one hour and discharged in only 5 minutes. The two suction tubes are 48 inches in diameter and 131 feet 3 inches long, mounted forward. The two I.H.C. Holland dredge pumps have 9-foot- 1-inch-diameter impellers, and each housing weighs 19 tons. Rated hourly capacity is 22,000 cubic meters at a manometric lift of 72 feet. The pumps are each driven by a 1,400 horsepower electric motor. All dredging operations are from the bridge. Overflow valves, which allow surplus water in the dredge mixture to flow freely overboard, are incorporated at several levels. For discharge of spoil, 26 conical bottom valves that are 11 feet 10 inches in diameter, and arranged in two rows, permit rapid expulsion. The vessel's overall length is 469 feet 2 inches; dredging depth is up to 114 feet 10 inches. The ship accommodates a crew of 60, is air conditioned, has a helicopter landing pad and bow-thrusters, and uses a 20-ton electric crane for general hoisting.

R

A0313 "Rubber Bearings Survive Rigorous Job," World Dredging and Marine Construction, Vol 18, No. 8, Aug 1982, pp 18-21.

The use of Johnson Duramax demountable rubber bearings in the cutterhead of a large dredge provided four advantages: low initial cost, extra long service life, reduced replacement labor, and less dredge downtime. During a job involving dredging of 22 million cubic yards of hard rock and soil using four dredgers, one set of the rubber bearings logged over 16,000 hours of operation without failure. Upon removal, wear was found to be uniform, and there were no signs of pitting, tearing, or hard abrasion. The bearing is made up of several staves of keystone-sided shape; the entire complement forming a cylinder. The rubber used is a special single durometer nitrile compound, impervious to chemical corrosives, abrasion resistant, and capable of absorbing heavy dredging impacts. The durometer rating (hardness) is chosen to give a solid support with optimum lubricating properties, thereby eliminating need for metal backing. The bearing is constantly flushed with seawater, the perfect lubricant because of its noncompressibility, constant availability, and affinity with rubber and metal surfaces. Replacement time is only a fraction of that for similar sized conventional flange bearings.

S

A0314 "Silt Density Measurements at Europort," Dredging and Port Construction, Series 2, Vol 8, No. 5, May 1981, pp 19-24.

Rotterdam's Europort and Maas Flats entrances have had to be dredged progressively deeper owing to the increasing size of tankers. Design depth was 57 feet at opening in 1971, but two increases have taken place to advance net draught to 68 feet, and 72 feet is being considered. The bottom is thick, black silt, gradually getting denser for the bottom 3 to 4 meters. Echo soundings are unreliable from this silt. A "nautical bottom" was eventually defined at a silt volume weight limit of 1,200 kg/m^3, which is a relative density of 1.2 in relation to clear water. Based on this definition, two new in situ measuring devices were devised to accurately determine the 1,200 kg/m^3 boundary from a vessel. Both devices use a radiation source and absorbance principles, one directly and one by backscatter. Detected radiation intensity indicates volume weight of the material through which radiation passes at a fixed distance. The detection accuracy of the H-shaped direct transmitter is 3 cm, and that of the backscatter gauge is 15 cm. Both instruments must sink through the silt of their own weight, and the H-shaped version is less effective at this. At present, as many as 60-70 measurements per day can be made; one vessel is kept busy performing measurements 40 percent of the time. Many improvements have been added, including computerizing the calculations and installing more efficient mechanical means of lowering the device. Sounding charts and nautical charts are now produced weekly by this system.

A0315 "Steam-Powered Dredge Computer Controlled," Ocean Industry, Vol 4, No. 4, Apr 1969, pp 7-8.

The trailing suction, hopper-dredger Hillah was the first of its type to be equipped with an automatic data logger, an electronic computer that handles massive amounts of data relating to the behavior of the ship, its machinery, and the dredging operations. It was built by I.H.C. Holland for the Iraqi Ports Administration to work in the 30-mile waterway linking Basrah with the Arabian Gulf. The ship has an overall length of 394 feet, with a beam of 62 feet, and accommodations for 81 officers and crew in air conditioned space. Twin suctin tubes, one on each side, amidship, can dredge to 71 feet. Maximum hopper capacity is 5,000 cubic yards. In contrast to most dredgers of this type, the Hillah can discharge spoil directly overboard, into barges, or via a floating pipeline up to a distance of 1,320 feet. It is highly maneuverable through the use of twin rudders, controllable-pitch propellers, and bowthrusters. The main engines and most other machinery also is powered differently--by steam. Two oil-fired Aalborg boilers are used, the largest of their type ever built thus far. Together, they can produce 60 tons of superheated steam hourly at a temperature of 300 degrees C. Hillah's modern appearance, steam power, and the far-reaching use of electronic aids make this vessel a remarkable member of the family of trailing-suction dredgers.

A0316 "Submarine Blasting," Blasters Handbook, Explosives Products Division, E. I. DuPont de Nemours and Co., Inc., pp 365-372.

Using explosives underwater is often needed for removal of rock when deepening harbors or channels, laying pipelines, or for other specialized jobs. Two types of submarine blasting are discussed: the "drill and blast method" (using drilled holes) and the "dobying method" (charges are detonated on rock surface). A key point of the drill and blast method is that drilling must be to proper depth (6 to 10 feet) to ensure later adequate dredging. Typically, boreholes are 3.5 to 6 inches in diameter. In soft formations, less explosives are needed. With "hard to shoot" rock, 6 pounds or more of explosive per cubic yard of drilled rock may be needed. A gel explosive often is used because of good "coupling" with rock and greater energy transmission. In unconsolidated rock, pumpable products are not recommended because they can fill voids and be excessively loaded. Solid cartridges are used in this case. Because of hazards in detonation, submarine blasting usually is broken into smaller series than for under dry conditions. Dobying mostly is used for excessive water depths where drilling is difficult, in strong tides or currents, in remote areas without drills, in blasting coral, and in removal of high spots. Dobying requires three times more explosive (powder factor) than does drilling. Dobying also requires good coupling with rock after overlying silt is removed, usually by a water jet, pumping, or clam-shell digging. Protection measures such as delays and bubble walls are used when blasting near structures.

A0317 "Submarine Pipe Laying for Ninian Field," International Dredging and Port Construction, Series 2, Vol 4, No. 2, Dec 1976, pp 25-27.

This article describes the placement of a 4-km pipeline (91-cm-diameter concrete coated pipe) between Culness and Firth Vess in the Shetlands. Initially, a crushed rock causeway was constructed to enable a dragline to stand. The dragline was used to retrieve more crushed rock (brought in on barges) and load it on lories for movement to a construction site to form rock bunds. The bunds later enclosed peat removed as overburden and stored for later replacement. After peat and rock removal along the route, and grading of the rock at the construction site (220 by 56 m), winches were brought in. Blasting on both ends and rock removal was carried out down to the pipeline formation level. The 12-m-long pipes were moved to the construction site by barge, offloaded with a crane on the causeway, and positioned for welding into 22 parallel strings of 180-m length. Welds were inspected by X-ray radiography, and each section was tested to 2,500 pounds per square inch pressure. Pulling wires of 5.5-cm diameter were used to pull the pipe strings from one shore terminus to the other. As each 180-m increment of pipe moved forward, another was rolled onto the center line and welded in place. When the entire 4-km line was pulled across, the line again was pressure tested. Replacement of peat and reinstatement of the site areas were the completion steps.

A0318 "Submersible Dredge Development," American Shore and Beach Preservation Association Newsletter 3, p 3.

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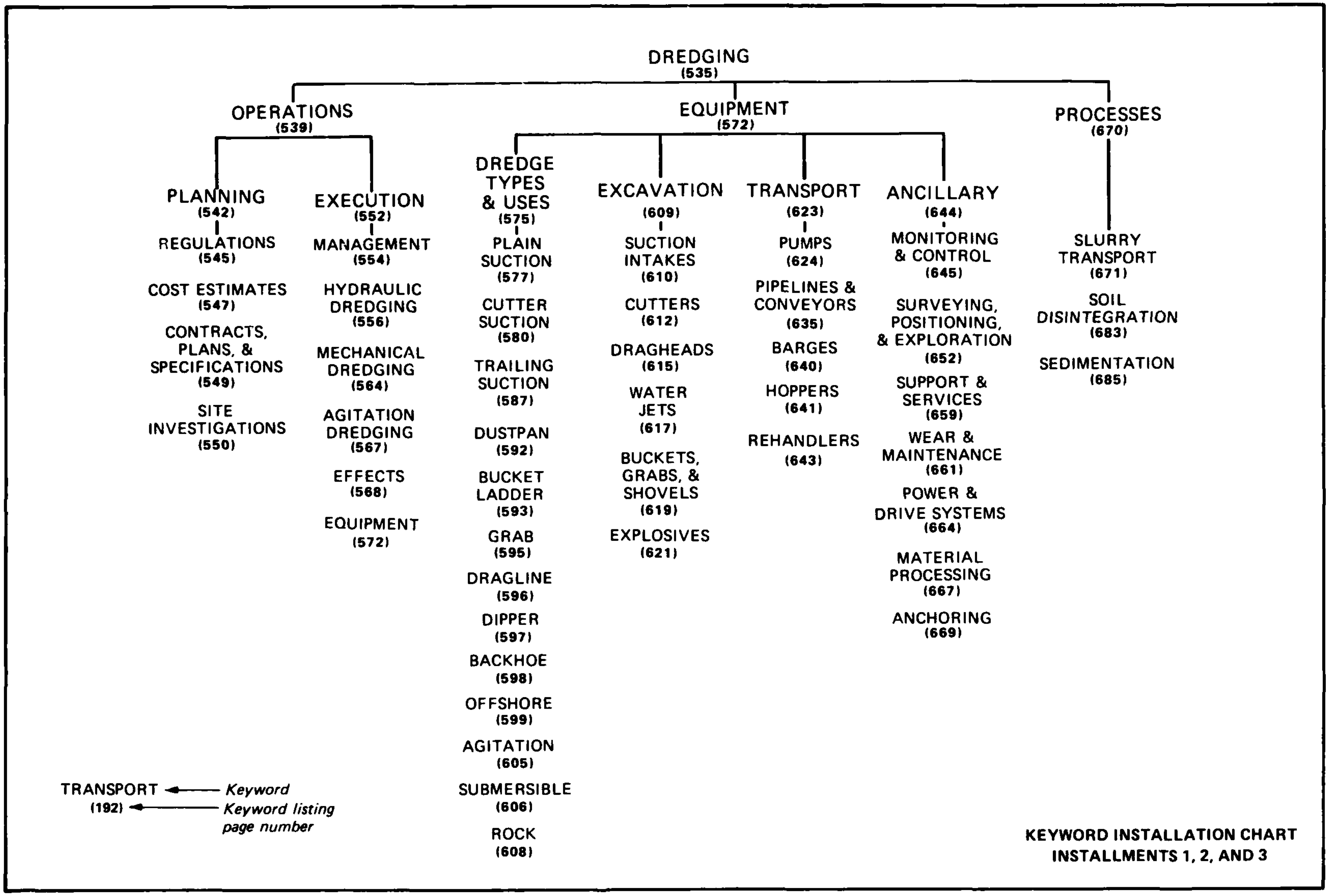

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Z

A0328 "Zinc Anodes Protect Offshore Pipelines," World Dredging and Marine Construction, Vol 18, No. 8, Aug 1982, p 29.

The Zinc Institute notes that, once a pipeline is laid offshore, there is no easy access to the pipe for monitoring, repair, or maintenance. Therefore, the urgency of installing a reliable zinc anode protection system is outlined. Electrochemical processes in sea water destroy metal pipes by corrosion--the action of numerous galvanic cells on the pipe's surface. An external source to counteract and reverse destructive electric currents, and which sacrifices itself to supply needed current, is the zinc anode in the form of tapered "bracelets." Zinc bracelets are sized for 20-year or 40-year life on 1,000-foot spacing (pipes 12 inches and larger) or on 500-foot spacing (pipes less than 12 inches). The cost of such a system usually is about 1 percent of the entire pipeline cost for a 40-year protective anode system. A single leak in a 20-inch pipe in 200 feet of water would cost more than initial protection for 200 miles of the line for 40 years. The bracelets ideally should be installed with care, for continuity to the pipe, at the coating yard and again just before the anoded joint is added to the pipeline. Most importantly, pipeline potentials should be checked for attainment of protection during pipelaying; the most critical point for checking is midway between bracelet anodes.

W

A0326 "Walking, Self-Elevating Cutter-Suction Dredge Platform from IHC," Europort '71 Marine Engineers Review, Vol 16, 1971, p 16.

A unique dredging device designed by I.H.C. Holland was displayed at Europort '71. It is a revolutionary design for a stationary cutter-suction dredger mounted on a platform similar to those used for offshore oil drilling. Cutter-suction dredgers usually are limited to working in water with waves of less than about 3 feet. The new L-shaped platform of pontoons has three spud rotors, with a pair of spuds located at the end of each arm of the L, and a third pair at the angle of the L. The spuds are self-elevating and the entire platform can "walk" by rotating the elevated spuds. The L is formed by two 7- × 30-m pontoon sections between which the cutter ladder is moved during dredging. The dredge pump and cutter drive motor are mounted in the middle of the ladder, the upper half of which is enclosed. The dredge can operate to 80 feet in waves of 10 feet and winds of Force 7. In hurricane conditions, the platform is stabilized on all six spuds. Spoil is discharged by pipeline or into barges. An ingenious mooring system prevents barges from colliding with the pontoon in rough weather. The cutter is made for cutting through hard rock bottoms, and special effort was made in allowing rapid cutter replacement. A special trolley transports the new and used cutters to and from the ladder extremity, and changing cutters takes less than 6 minutes with only two crewmen.

A0327 "Waterless Dredge Designed for Industrial Sludge Removal," World Dredging and Marine Construction, Vol 16, No. 8, Aug 1980, pp 9-11.

Materials produced during industrial processes and from removal of air and water pollutants have been placed in sludge lagoons for decades, many times very near the industrial or municipal plants that generated them. Demands for space and proper permanent disposal requirements have led cities and industries to transport wet sludges long distances for final disposal. Conventional floating suction dredging is inefficient for this process by adding too much water (2 gallons water for each gallon of sludge) and increasing disposal volume and cost. A new design of dredge has been created specifically for mining industrial and municipal sludges. The Model 8-180 of The Waterless Dredging Company adds a minimum of water (from 0 to 10 percent by volume), and dredges to 16 feet. Special features include a shrouded rollover cutterhead, submerged pump, and constant tension, four-winch/cable positioning and propulsion system. The dredge is propelled by starboard and port swing winches and cables. As the bow swings to the left, the face of the rollover cutterhead is open and fills with sludge while displacing any water; only thick sludge is pumped. At the end of its swing, the head is rolled down and over 180 degrees so the face is open properly for a swing to the right. A 12-inch inlet, but only 8-inch outlet and a submersible pump allows lower intake velocity and the ability to pump thicker material. Motors, pumps, the hydraulic drives, and the winch system also are described. Removal rate of sludge is about 200 cubic yards per hour.

depth with removal of relatively easily dredged material. However, as depth needs increase, the chances of encountering harder rock also increase. The higher cost for dredging rock has been estimated at 50 times that of removing equal volumes of soft material. Traditional dredging, limited by the types of rock dealt with economically, has led to fragmentation methods by drilling and blasting. Two blasting methods are discussed: the "Swedish" and "British" methods. The Swedish concept is that an explosive should be used which has a limited lift if undetonated, and then becomes inert and not dangerous to subsequent dredging. Hence, cartridges were pneumatically inserted that contained detonators. British contractors insist this is too dangerous, since 20 percent of charges may be undetonated. The British method uses detonating cord from the surface and only uses detonators on the surface to initiate the cord. Submarine blasting gelatin has been the most recommended technique. This geletin contains 87 percent nitroglycerine and detonates at high velocity under large heads of water. Since most port deepening is in 20 to 60 feet of water, British contractors often use a slightly cheaper explosive and free-floating drilling operations.

U

A0323 "'Ultimate' Dredge Announced by Stevin," World Dredging and Marine Construction, Vol 15, No. 1, Jan 1979, p 90.

A new multipurpose cutter-suction dredge, the "Stevin 80," has been developed to overcome obstacles to dredging hard material in heavy swell. After analyzing weak points of other dredges, a semisubmersible design was arrived at. The dredge is supported on eight legs on a seabed or river bottom. Until this development, dredging in exposed areas could be carried out only during scarce intervals of calm seas; operations were costly and limited. The new dredge permits building ports in locations previously considered unrealistic, dredging harbors without waiting for breakwater construction, and pipeline trenching in rough coastal waters for mining ventures. It can also be used for broadening or deepening narrow and shallow harbors and for construction of artificial offshore islands. Construction cost was $96 million; it will hire out at $600,000 per week based on 7 days and 24 hours per day operations. Specifications include an overall length of 623 feet (crane to crane), width of 220 feet, height of 246 feet, cutting width of 270 feet, and a dredging depth of 105 feet. Total installed horsepower on the vessel is 35,000. Total weight is 29,000 metric tons.

A0324 "Underwater Dredge May Replenish Beach Sand," Ocean Industry, Vol 3, No. 10, Oct 1968, pp 5-6.

Because many coastal beaches are depleted of sand by storms or the erosion of currents and winds, a low-cost means of replenishment has been devised. In contrast to conventional dredges in nearshore applications that are susceptible to operating difficulties in rough weather and heavy surf, a family of submersible vehicles has been built. They crawl on the sea floor with spherical wheels fitted with traction cleats. Another function of the spherical wheels is to supply ballast or flotation as desired. For shallow water excavations, the crawlers use conventional diesel engines, with a snorkel supplying intake air, and a conduit for exhaust. The snorkel is fitted with lights and radar and audible signal devices for warning surface traffic. The center of gravity of the submerged vehicles is below the center of buoyancy to assure stability in shallow water operations. For deep work, the spherical wheels can be evacuated and used as receiving reservoirs for hydrostatically powered devices used to drive the vehicle. The control system has two-way communications which give shore-based personnel constant information on what the vehicle sees and local bottom characteristics. The developer lists 22 general areas of need that could be more efficiently serviced by the type of submersible vehicle described.

A0325 "Underwater Drilling and Blasting in Relation to Dredging," Dock and Harbour Authority, Vol 49, No. 572, June 1968, pp 71-72.

The majority of ports worldwide are in need of deepening as ships get larger and require deeper water. Most ports maintain a practical

A0322 "The Great Australian Dredger Sir Thomas Hiley," World Dredging and Marine Construction, Vol 8, No. 1, Jan 1972, pp 28-29.

Growth of Queensland, Australia, has been steady in recent years, particularly in the volume of port trade. Because of increased trade, few natural harbors, and the increasing need for servicing larger tonnage ships, the State of Queensland purchased the new dredger. The three principal Queensland harbors of Brisbane, Gladstone, and Weipa regularly handle ships of 60,000-ton capacity. However, the coal trade is designing facilities for 100,000-ton ships, and other bulk trades in bauxite, aluminum, oil, sugar, salt, grain, fertilizer, and sand look forward to larger ships, cheaper freight, and the need for deeper and wider channels. The new dredger is capable of dredging to 65 feet (enough to handle 200,000-ton ships) by removing solid material at a rate of 120 tons per minute. She is 335 feet long and has a 12-knot speed, powered by a diesel-electric system. Spoil can be dumped through the bottom, pumped to barges alongside, or pumped to a shore pipeline to reclaim land areas. The ship was designed by I.H.C. Holland and built at Maryborough by Walkers, Ltd. The vessel contains a comprehensive monitoring and control room, and all dredging operations are carried out from the enclosed bridge. An alarm sounds when full load is achieved, and further dredged material is automatically diverted over the side.

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A0320 "T. L. James, Gulf Coast Trailing Co., Christen Two New Dredges in Joint Venture," World Dredging and Marine Construction, Vol 16, No. 11, Nov 1980, pp 14-16.

Two dredges, a 265-foot-long cutter-suctio dredge and a 197-foot-long split-hull hopper dredge, were christened in New Orleans at waterfront ceremonies. The cutter-suction dredge "Bill James" displaces 4,364 long tons at its maximum draft of 11 feet 8 inches, and its dredging operations are powered by three in-line 4,400 BHP Cooper-Bessemer diesel electric engines with 3,000 kilowatt generators. It has a 121-foot cutterhead ladder extending from the bow and a spud frame at the stern of almost 75 feet. The split-hull hopper "Atchafalaya" has a loaded draft of 14 feet and a light draft of 5 feet. Material is pumped into the 1,300-cubic-yard capacity hopper through a dragarm that can extend to 65 feet below the vessel. Material can be discharged by opening the hull or by pumping. Corps of Engineers and industry speakers at the christening ceremonies agreed that these new dredges are being developed at an increasing rate by private industry and being put into operation to handle a larger part of the load that the Corps once handled. Industry has demonstrated its confidence in this trend by committing major capital investment, and the Corps has continued to reduce its own fleet by retiring vessels.

A0321 "Tenth Annual Directory of World Dredges and Suppliers," World Dredging and Marine Construction, Vol 12, No. 2, Jan 1976, pp 6-71.

Dredges are essential to international commerce through maintenance of navigable waterways and development of ports. A great amount of use is being made of dredged materials: highways, airports, real estate, recreation areas, and even agricultural land. This tenth annual directory for the first time includes dredge industry equipment and service suppliers. The basic purposes of the directory are to document and illustrate current trends, provide a service to the allied industries, encourage technical information transmittal, and contribute to advancing technology. The dredge types listed are categorized into two main types, mechanical and hydraulic. Mechanical includes bucket ladder, dipper, grab, backhoe, clamshell, and their varieties, while hydraulic includes self-propelled suction hopper, cutterhead suction, plain suction, dustpan suction, and a number of varieties. These are coded in the directory. A total of 2,571 dredges are listed for 66 countries which reported operating dredges. The United States operates the most with 691, while the Netherlands is second at 387, and Japan is third with 224. The only other country possessing over 100 is Canada with 113. The U. S. Army Corps of Engineers owns 42 dredges stationed in 17 different Corps Districts. Ten pages of the directory contain an alphabetical index to dredge suppliers and a specialty listing of parts, supplies, and services offered.

An experimental submersible sand dredge may prove to be more efficient at restoring beaches than conventional surface dredges because of ability to avoid nearshore wave action and bad weather. One such dredge devised by Ocean Science and Engineering, Inc., is being tested at Fort Lauderdale and Fort Pierce, Florida. The dredge has two modules connected by a crawlway, and a lockout chamber for diver operators. The vehicle is mounted on tracks and moves into the water attached to an umbilical cord which provides electricity and breathing air. A 30-foot-long cutterhead is mounted on the front of the vehicle, and sand is pumped directly ashore. Initial trails will use a 12-inch pipe. The unit is expected to be about as efficient as a boating dredge of similar size in moving equal amounts of material, but its overall performance will be better because of fewer weather delays. Initial tests will involve moving about 100,000 cubic yards of sand to the beach from an area 2,000 feet from shore. A study of Florida, where beach erosion is adversely affecting tourism, has identified some $60 million in beach replenishment projects.

A0319 "Success of Savage River Slurry Pipeline Points Way to Low-Cost Transportation," Engineering and Mining Journal, Vol 3, Jan 1969, pp 64-65.

The world's first long-distance (53-mile) slurry pipeline for iron ore was put into service on October 26, 1967, in Tasmania, Australia. A number of large construction, engineering, mining, and financial organizations were involved. Several alternative transportation modes were considered and found to be too costly. However, the $79 million project commitment was based on the absolute necessity of success; and this was accomplished. Several feasibility studies were made initially, and other slurry pipeline projects were visited. The line extends from an open-pit mine in mountainous terrain to Port Latta. A 9-inch diameter buried line was used to transport a concentrate which would have a 5 percent maximum of particles over 200 mesh size. It was found essential to demagnetize the ore, pump at 55 to 60 percent solids at a discharge pressure of 2,000 pounds per square inch, and utilize slopes of less than 14 percent. If this slope were exceeded, material would slide and cause clogs. Thus, a safe maximum slope of 10 percent was used. Receiving facilities included storage and thickening units, as well as filtering, balling, and pelletizing equipment. The pellet products contain 67.5 percent iron and about 1 percent silicon dioxide. Overall recovery efficiency is 49 percent. Maintenance is minimal, but because of gangue buildup, scraper pigs are pumped through the pipeline every 2 or 3 months to keep it clear.

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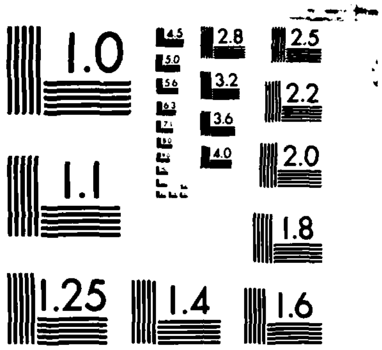

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